THE FOUNDATIONS OF BOTANY

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FOUNDATIONS OF BOTANY

BY

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GINN & COMPANY

BOSTON · NEW YORK · CHICAGO · LONDON

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The Athenæum Press
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PREFACE

THIS book is written upon the same plan as the author's *Elements of Botany*. A few chapters stand here but little altered from the former work, but most of them have been rewritten and considerably enlarged, and many new ones have been added. The principal changes in the book as a whole are these :

1. Most of the discussion of ecological topics is put by itself, in Part II.

2. The amount of laboratory work on the anatomy and physiology of seed-plants is considerably increased and additional experiments are introduced.

3. The treatment of spore-plants is greatly extended, so as to include laboratory work on the most important groups.

4. The meagre Flora which accompanied the old *Elements* has been replaced by one which contains fairly full descriptions of more than eight hundred species of plants. Most of these are wild, but a considerable number of cultivated species have been included, mainly for the convenience of schools in large cities.

Ample material is offered for a year's course, four or five periods per week. The author is well aware that most schools devote but half a year to botany, but the tendency sets strongly toward allowing more time for this subject. Even in schools where the minimum time allowance is devoted to botany, there is a distinct advantage in being provided with a book which allows the teacher considerable option as regards the kind and amount of work which he shall offer to his classes.

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Suggestions are made in the teacher's *Handbook*, which accompanies this volume, in regard to shaping half-year courses.

The latest authorities in the various departments of botany have been consulted on all doubtful points, and the attempt has been to make the book scientifically accurate throughout, yet not unduly difficult.

Most of the illustrations have been redrawn from those in standard German works of an advanced character, or drawn from nature or from photographs, expressly for this book. Besides the sources of drawings acknowledged in the author's *Elements*, many cuts have been taken from the botanies of Frank, Prantl, Detmer, Murray, and Bennett and Murray, as well as from Schimper's *Pflanzengeographie*.

Of the drawings from nature or from photographs, some figures, and Plates I, VII, and VIII, are by Mr. Edmund Garrett of Boston; several figures, the Frontispiece, and Plates II, IV, X, XI, are by Mr. Bruce Horsfall of New York; several figures are by Mr. F. Schuyler Mathews of Boston; a large number of figures and Plate V are by Mr. E. N. Fischer of Boston; several figures are by Mr. E. R. Kingsbury of Boston and Dr. J. W. Folsom of the University of Illinois.

Thanks for the use of photographs are due to Mr. H. G. Peabody of Boston (Fig. 234), to Mr. J. H. White of Boston (Figs. 32, 75, 222), to Professor Conway MacMillan of the University of Minnesota (Frontispiece), and to Professor F. V. Coville of Washington (Plate VII). Figs. 28 and 275 are taken by permission from the *Primer of Forestry*, issued by the Division of Forestry, U. S. Department of Agriculture. Figs. 263, 264, 276 are copied by permission from Professor W. J. Beal's *Seed Dispersal*, and Figs. 226, 229, 233 from Professor W. M. Davis's *Physical Geography*. Fig. 269 is from a photograph by Professor C. F. Millspaugh of Chicago. Plate IV is from a photograph by Dr. H. J. Webber.

Most of the redrawn illustrations (not microscopical) from various European sources are by Mr. Fischer. Most of the microscopical ones (and a number of figures from nature) are by Dr. J. W. Folsom of the University of Illinois, and many of both classes are by Mr. Mathews. Thanks are due to Professor J. M. Holzinger of the Winona (Minn.) State Normal School, to Professor L. Murbach of the Detroit High School, and to Mr. I. S. Cutter of Lincoln, Nebraska, for their many discriminating criticisms of the proof of Parts I and II. Mr. Samuel F. Tower of the Boston English High School, Professor Charles V. Piper of the Washington State Agricultural College, and Dr. Rodney H. True, Lecturer on Botany at Harvard University, have all read the whole or large portions of Part I and given valuable suggestions. Professor W. F. Ganong, of Smith College, has read and criticised Part II.

The chapters on spore-plants, excepting a small amount of matter retained from the *Elements of Botany*, are entirely the work of Mr. A. B. Seymour of the Cryptogamic Herbarium of Harvard University.

The author has attempted to steer a middle course between the advocates of the out-of-door school and of the histological school of botany teaching. He has endeavored never to use a technical term where he could dispense with it, and on the other hand, not to become inexact by shunning necessary terms. In deciding questions of this sort, *a priori* reasoning is of little value ; one must ascertain by repeated trials how much of a technical vocabulary the average beginner in botany can profitably master. The teacher who has discovered that not one of the boys in a division of thirty-six pupils knows that his own desk-top is of cherry wood may well hesitate about beginning his botany teaching with a discourse on centrospheres and karyokinesis. It has been assumed throughout this book that, other things being equal, the knowledge is of

most worth which touches the pupil's daily life at the most points, and therefore best enables him to understand his own environment. On the other hand, the author has no sympathy with those who decry the use of apparatus in botany teaching in secondary schools and who would confine the work of their pupils mainly within the limits of what can be seen with the unaided eye. If the compound microscope plainly reveals things shown only imperfectly by a magnifier and not seen at all with the naked eye, — use the microscope! If iodine solution or other easily prepared reagents make evident the existence of structures or substances not to be detected without them, — then use the reagents! No one thinks of denying a boy the use of a spyglass or a compass for his tramps afield or his outings in a boat because he has not studied physics. No one would refuse to let an intelligent boy or girl use a camera because the would-be photographer had not mastered the chemical reactions that follow upon the exposure of a sensitized plate. Yet it is equally illogical to defer some of the most fascinating portions of botanical study until the college course, to which most never attain. When the university professor tells the teacher that he ought not to employ the ordinary appliances of elementary biological investigation in the school laboratory because the pupils cannot intelligently use them, the teacher is forced to reply that the professor himself cannot intelligently discuss a subject of which he has no personal knowledge. The pupils are deeply interested; they prove by their drawings and their recitations that they have seen a good way into plant structures and plant functions; then why not let them study botany in earnest?

J. Y. B.

Cambridge, January, 1901.

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FOUNDATIONS OF BOTANY

INTRODUCTION

"Botany is the science which endeavors to answer every reasonable question about plants." [1]

THE plant is a living being, provided generally with many parts, called *organs*, which it uses for taking in nourishment, for breathing, for protection against its enemies, and for reproducing itself and so keeping up the numbers of its own kind. The study of the individual plant therefore embraces a variety of topics, and the examination of its relation to others introduces many more subjects.

Morphology, or the science of form, structure, and so on, deals with the plant without much regard to its character as a living thing. Under this head are studied the forms of plants and the various shapes or disguises which the same sort of organ may take in different kinds of plants, their gross structure, their microscopical structure, their classification, and the successive stages in the development of the individual plant.

Plant Physiology treats of the plant in action, how it lives, breathes, feeds, grows, and produces others like itself.

Geographical Distribution, or botanical geography, discusses the range of the various kinds of plants over the

[1] Professor George L. Goodale.

earth's surface. Another subdivision of botany, usually studied along with geology, describes the history of plant life on the earth from the appearance of the first plants until the present time.

Systematic Botany, or the classification of plants, should naturally follow the examination of the groups of seed-plants and spore-plants.

Plant Ecology treats of the relations of the plant to the conditions under which it lives. Under this division of the science are studied the effects of soil, climate, and friendly or hostile animals and plants on the external form, the internal structure, and the habits of plants. This is in many respects the most interesting department of botany, but it has to be studied for the most part out of doors.

Many of the topics suggested in the above outline cannot well be studied in the high school. There is not usually time to take up more than the merest outline of botanical geography, or to do much more than mention the important subject of *Economic Botany* — the study of the uses of plants to man. It ought, however, to be possible for the student to learn in his high-school course a good deal about the simpler facts of morphology and of vegetable physiology. One does not become a botanist — not even much of an amateur in the subject — by reading books about botany. It is necessary to study plants themselves, to take them to pieces and make out the connection of their parts, to examine with the microscope small portions of the exterior surface and thin slices of all the variously built materials or *tissues* of which the plant consists. All this can be done with living specimens or with those taken

from dead parts of plants that have been preserved in any suitable way, as by drying or by placing in alcohol or other fluids which prevent decay. Living plants must be studied in order to ascertain what kinds of food they take, what kinds of waste substances they excrete, how and where their growth takes place and what circumstances favor it, how they move, and indeed to get as complete an idea as possible of what has been called the behavior of plants.

Since the most familiar and most interesting plants spring from seeds, the beginner in botany can hardly do better than to examine at the outset the structure of a few familiar seeds, then sprout them and watch the growth of the seedlings which spring from them. Afterwards he may study in a few typical examples the organs, structure, and functions of seed-plants, trace their life history, and so, step by step, follow the process by which a new crop of seeds at last results from the growth and development of such a seed as that with which he began.

After he has come to know in a general way about the structure and functions of seed-plants, the student may become acquainted with some typical cryptogams or spore-plants. There are so many groups of these that only a few representative ones can be chosen for study.

Part I

STRUCTURE, FUNCTIONS, AND CLASSIFICATION OF PLANTS

CHAPTER I

THE SEED AND ITS GERMINATION

1. Germination of the Squash Seed. — Soak some squash seeds in tepid water for twelve hours or more. Plant these about an inch deep in damp sand or pine sawdust or peat-moss in a wooden box which has had holes enough bored through the bottom so that it will not hold water. Put the box in a warm place (not at any time over 70° or 80° Fahrenheit),[1] and cover it loosely with a board or a pane of glass. Keep the sand or sawdust moist, but not wet, and the seeds will germinate. As soon as any of the seeds, on being dug up, are found to have burst open, sketch one in this condition,[2] noting the manner in which the outer seed-coat is split, and continue to examine the seedlings at intervals of two days, until at least eight stages in the growth of the plantlet have been noted.[3]

[1] Here and elsewhere throughout the book temperatures are expressed in Fahrenheit degrees, since with us, unfortunately, the Centigrade scale is not the familiar one, outside of physical and chemical laboratories.

[2] The student need not feel that he is expected to make finished drawings to record what he sees, but some kind of careful sketch, if only the merest outline, is indispensable. Practice and study of the illustrations hereafter given will soon impart some facility even to those who have had little or no instruction in drawing. Consult here Figs. 9 and 89.

[3] The class is not to wait for the completion of this work (which may, if desirable, be done by each pupil at home), but is to proceed at once with the examination of the squash seed and of other seeds, as directed in the following sections, and to set some beans, peas, and corn to sprouting, so that they may be studied at the same time with the germinating squashes.

Observe particularly how the sand is pushed aside by the rise of the young seedlings. Suggest some reason for the manner in which the sand is penetrated by the rising stem.

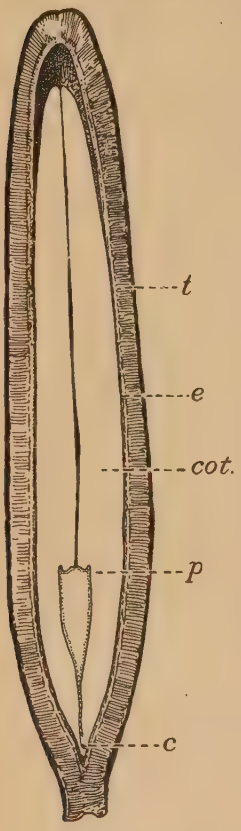


FIG. 1.—Lengthwise Section of a Squash Seed. (Magnified about five times.)

2. Examination of the Squash Seed. — Make a sketch of the dry seed, natural size. Note the little scar at the pointed end of the seed where the latter was attached to its place of growth in the squash. Label this *hilum*.

Note the little hole in the hilum; it is the *micropyle*, seen most plainly in a soaked seed. (If there are two depressions on the hilum the deeper one is the micropyle.)

Describe the color and texture of the outer coating of the seed. With a scalpel or a very sharp knife cut across near the middle a seed that has been soaked in water for twenty-four hours. Squeeze one of the portions, held edgewise between the thumb and finger, in such a way as to separate slightly the halves into which the contents of the seed is naturally divided. Examine with the magnifying glass the section thus treated, make a sketch of it, and label the shell or covering of the seed and the kernel within this.

Taking another soaked seed, chip away the white outer shell, called the *testa*, and observe the thin, greenish inner skin (Fig. 1, *e*), with which the kernel of the seed is closely covered.[1]

Strip this off and sketch the uncovered kernel or *embryo*. Note that at one end it tapers to a point. This pointed portion, known as the *hypocotyl*, will develop after the seed sprouts into the stem of the plantlet, like that shown at *c* in Fig. 2.

Split the halves of the kernel entirely apart from each other,

[1] See footnote 2 to Sect. 18.

noticing that they are only attached for a very little way next to the hypocotyl, and observe the thickness of the halves and the slight unevenness of the inner surfaces. These halves are called seed-leaves or *cotyledons*.

Have ready some seeds which have been soaked for twenty-four hours and then left in a loosely covered jar on damp blotting paper at a temperature of 70° or over until they have begun to sprout.

Split one of these seeds apart, separating the cotyledons, and observe, at the junction of these, two very slender pointed objects, the rudimentary leaves of the *plumule* or first bud (Fig. 1, *p*).

3. Examination of the Bean. —Study the seed, both dry and after twelve hours' soaking, in the same general way in which the squash seed has just been examined.[1]

Notice the presence of a distinct plumule, consisting of a pair of rudimentary leaves between the cotyledons, just where they are joined to the top of the hypocotyl. In many seeds (as the pea) the plumule does not show distinct leaves. But in all cases the plumule contains the *growing point*, the tip of the stem from which all the upward growth of the plant is to proceed.

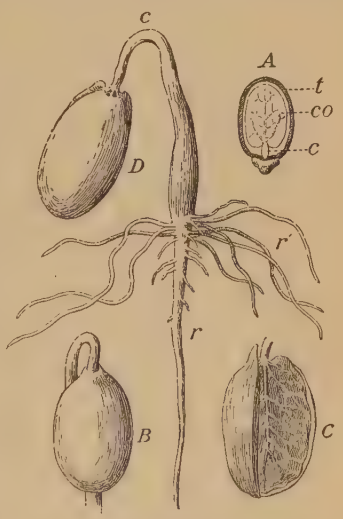


FIG. 2. — The Castor Bean and its Germination.

A, longitudinal section of ripe seed; *t*, testa; *co*, cotyledon; *c*, hypocotyl; *B*, sprouting seed covered with endosperm; *C*, same, with half of endosperm removed; *D*, seedling; *r*, primary root; *r'*, secondary roots; *c*, arch of hypocotyl.

Make a sketch of these leaves as they lie in place on one of the cotyledons, after the bean has been split open.

[1] The larger the variety of bean chosen, the easier it will be to see and sketch the several parts. The large red kidney bean, the horticultural bean, or the lima bean will do well for this examination.

Note the cavity in each cotyledon caused by the pressure of the plumule and of the hypocotyl.

4. Examination of the Pea. — There are no very important points of difference between the bean and pea, so far as the structure of the seed is concerned, but the student should rapidly dissect a few soaked peas to get an idea of the appearance of the parts, since he is to study the germination of peas in some detail.

Make only one sketch, that of the hypocotyl as seen in position after the removal of the seed-coats.[1]

5. Germination of the Bean or the White Lupine, the Pea, and the Grain of Corn. — Soak some beans or lupine seeds as directed in Section 3, plant them,[2] and make a series of sketches on the same general plan as those in Fig. 9.

Follow the same directions with some peas and some corn. In the case of the corn, make six or more sketches at various stages to illustrate the growth of the plumule and the formation of roots; first a main root from the base of the hypocotyl, then others more slender from the same region, and later on still others from points higher up on the stem (see Fig. 15). The student may be able to discover what becomes of the large outer part of the embryo. This is really the single cotyledon of the corn (Fig. 6). It does not as a whole rise above ground, but most of it remains in the buried grain, and acts as a digesting and absorbing organ through which the endosperm or food stored outside of the embryo is transferred into the growing plant, as fast as it can be made liquid for that purpose.

6. Germination of the Horse-Chestnut. — Plant some seeds of the horse-chestnut or the buckeye, study their mode of germination, and observe the nature and peculiar modifications of the parts.

Consult Gray's *Structural Botany*, Vol. I, pp. 19, 20.

7. Conditions Requisite for Germination. — When we try to enumerate the external conditions which can affect

[1] The teacher will find excellent sketches of most of the germinating seeds described in the present chapter in Miss Newell's *Outlines of Lessons in Botany*, Part I.

[2] The pupil may economize space by planting the new seeds in boxes from which part of the earlier planted seeds have been dug up for use in sketching, etc.

germination, we find that the principal ones are heat, moisture, and presence of air. A few simple experiments will show what influence these conditions exert.

8. Temperature. — Common observation shows that a moderate amount of warmth is necessary for the sprouting of seeds. Every farmer or gardener knows that during a cold spring many seeds, if planted, will rot in the ground. But a somewhat exact experiment is necessary to show what is the best temperature for seeds to grow in, and whether variations in the temperature make more difference in the quickness with which they begin to germinate or in the total per cent which finally succeed.

EXPERIMENT I

Relation of Temperature to Germination. — Prepare at least four teacups or tumblers, each with wet soft paper packed in the bottom to a depth of nearly an inch. Have a tightly fitting cover over each. Put in each vessel the same number of soaked peas. Stand the vessels with their contents in places where they will be exposed to different, but fairly constant, temperatures, and observe the several temperatures carefully with a thermometer. Take pains to keep the tumblers in the warm places from drying out, so that their contents will not be less moist than that of the others. The following series is merely suggested, — other values may be found more convenient. Note the rate of germination in each place and record in tabular form as follows:

No. of seeds sprouted in	24 hrs.	48 hrs.	72 hrs.	96 hrs.	etc.
At 32°,	——	——	——	——	——
At 50°,	——	——	——	——	——
At 70°,	——	——	——	——	——
At 90°,[1]	——	——	——	——	——

[1] For the exact regulation of the temperatures a thermostat (see *Handbook*) is desirable. If one is available, a maximum temperature of 100° or over should be tried.

9. Moisture. — What was said in the preceding section in regard to temperature applies also to the question of the best conditions for germination as regards the supply of moisture. The soil in which seeds grow out of doors is always moist; it rests with the experimenter to find out approximately what is the best amount of moisture.

EXPERIMENT II[1]

Relation of Water to Germination. — Arrange seeds in several vessels as follows:

In the first put blotting paper that is barely moistened; on this put some dry seeds.

In the second put blotting paper that has been barely moistened; on this put seeds that have been soaked for twenty-four hours.

FIG. 3. — Soaked Peas in Stoppered Bottle, ready for Exhaustion of Air.

In the third put water enough to soak the paper thoroughly; use soaked seeds.

In the fourth put water enough to half cover the seeds.

Place the vessels where they will have same temperature and note the time of germination.

Tabulate your results as in the previous experiment.

10. Relation of the Air Supply to Germination. — If we wish to see how soaked seeds will behave with hardly any air supply, it is necessary to place them in a bottle arranged

[1] This may be made a home experiment.

as shown in Fig. 3, exhaust the air by connecting the glass tube with an air-pump, which is then pumped vigorously, and seal the tube while the exhaustion is going on. The sealing is best done by holding a Bunsen flame under the middle of the horizontal part of the tube. A much easier experiment, which is nearly as satisfactory, can, however, be performed without the air-pump.

EXPERIMENT III

Will Seeds Germinate well without a Good Supply of Air? — Place some soaked seeds on damp blotting paper in the bottom of a bottle, using seeds enough to fill it three-quarters full, and close tightly with a rubber stopper.

Place a few other seeds of the same kind in a second bottle; cover loosely.

Place the bottles side by side, so that they will have the same conditions of light and heat. Watch for results, and tabulate as in previous experiments.

Most seeds will not germinate under water, but those of the sunflower will do so, and therefore Exp. III may be varied in the following manner:

Remove the shells carefully from a considerable number of sunflower seeds.[1] Try to germinate one lot of these in water which has been boiled in a flask to remove the air, and then cooled in the same flask. Over the water, with the seeds in it, a layer of cotton-seed oil about a half inch deep is poured, to keep the water from contact with air. In this bottle then there will be only seeds and air-free water. Try to germinate another lot of seeds in a bottle half filled with ordinary water, also covered with cotton-seed oil. Results?

11. Germination involves Chemical Changes.— If a thermometer is inserted into a jar of sprouting seeds, for

[1] These are really fruits, but the distinction is not an important one at this time.

instance peas, in a room at the ordinary temperature, the peas will be found to be warmer than the surrounding air. This rise of temperature is at least partly due to the absorption from the air of that substance in it which supports the life of animals and maintains the burning of fires, namely, *oxygen.*

The union of oxygen with substances with which it can combine, that is with those which will burn, is called *oxidation.* This kind of chemical change is universal in plants and animals while they are in an active condition, and the energy which they manifest in their growth and movements is as directly the result of the oxidation going on inside them as the energy of a steam engine is the result of the burning of coal or other fuel under its boiler. In the sprouting seed much of the energy produced by the action of oxygen upon oxidizable portions of its contents is expended in producing growth, but some of this energy is wasted by being transformed into heat which escapes into the surrounding soil. It is this escaping heat which is detected by a thermometer thrust into a quantity of germinating seeds.

EXPERIMENT IV

Effect of Germinating Seeds upon the Surrounding Air. — When Exp. III has been finished, remove a little of the air from above the peas in the first bottle. This can easily be done with a rubber bulb attached to a short glass tube. Then bubble this air through some clear, filtered limewater. Also blow the breath through some limewater by aid of a short glass tube. Explain any similarity in results obtained. (Carbon dioxide turns limewater milky.) Afterwards insert into the air above the peas in the same bottle a lighted pine splinter, and note the effect upon its flame.

12. Other Proofs of Chemical Action. — Besides the proof of chemical changes in germinating seeds just described, there are other kinds of evidence to the same effect.

Malt, which is merely sprouted barley with its germination permanently stopped at the desired point by the application of heat, tastes differently from the unsprouted grain, and can be shown by chemical tests to have suffered a variety of changes. If you can get unsprouted barley and malt, taste both and see if you can decide what substance is more abundant in the malt.

Germinating kernels of corn undergo great alterations in their structure; the starch grains are gradually eaten away until they are ragged and full of holes and finally disappear.

13. The Embryo and its Development. — The miniature plant, as it exists ready formed and alive but inactive in the seed, is called the *embryo*. In the seeds so far examined, practically the entire contents of the seed-coats consist of the embryo, but this is not the case with the great majority of seeds, as will be shown in the following chapter.

CHAPTER II

STORAGE OF FOOD IN THE SEED

14. Food in the Embryo. — Squash seeds are not much used for human food, though both these and melon seeds are occasionally eaten in parts of Europe; but beans and peas are important articles of food. Whether the material accumulated in the cotyledons is an aid to the growth of the young plant may be learned from a simple experiment.

15. Mutilated and Perfect Seedlings. — One of the best ways in which to find out the importance and the special use of any part of a plant is to remove the part in question and see how the plant behaves afterward.

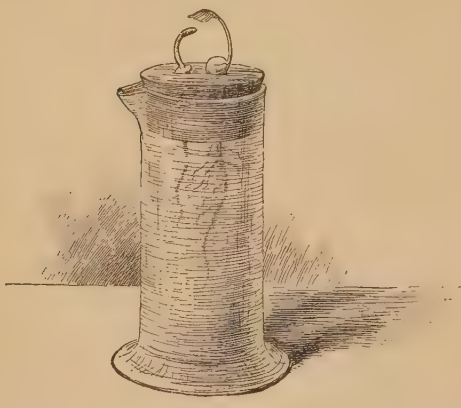


FIG. 4. — Germinating Peas, growing in Water, one deprived of its Cotyledons.

EXPERIMENT V[1]

Are the Cotyledons of a Pea of any Use to the Seedling? — Sprout several peas on blotting paper. When the plumules appear, carefully cut away the cotyledons from some of the seeds. Place on a perforated cork, as shown in Fig. 4, one or two seedlings from

[1] May be a home experiment.

which the cotyledons have been cut, and as many which have not been mutilated, and allow the roots to extend into the water. Let them grow for some days, or even weeks, and note results.

16. Food stored in Seeds in Relation to Growth after Germination. — If two kinds of seeds of somewhat similar character, one kind large and the other small, are allowed to germinate and grow side by side, some important inferences may be drawn from their relative rate of growth.

EXPERIMENT VI[1]

Does the Amount of Material in the Seed have anything to do with the Rate of Growth of the Seedling? — Germinate ten or more clover seeds, and about the same number of peas, on moist blotting paper under a bell-jar. After they are well sprouted, transfer both kinds of seeds to fine cotton netting, stretched across wide-mouthed jars nearly full of water. The roots should dip into the water, but the seeds must not do so. Allow the plants to grow until the peas are from four to six inches high.

Some of the growth in each case depends on material gathered from the air and water, but most of it, during the very early life of the plant, is due to the reserve material stored in the seed. Where is it in the seeds so far studied? Proof?

17. Storage of Food outside of the Embryo. — In very many cases the cotyledons contain little food, but there is a supply of it stored in the seed beside or around them (Figs. 2, 5, and 6).

I II

FIG. 5. — Seeds with Endosperm, Longitudinal Sections.

I, asparagus (magnified).
II, poppy (magnified).

18. Examination of the Four-o'clock Seed. — Examine the external surface of a seed[2] of the four-o'clock, and try the hardness of

[1] May be a home experiment. [2] Strictly speaking, a fruit.

the outer coat by cutting it with a knife. From seeds which have been soaked in water at least twenty-four hours peel off the coatings and sketch the kernel. Make a cross-section of one of the soaked seeds which has not been stripped of its coatings, and sketch the section as seen with the magnifying glass, to show the parts, especially the two cotyledons, lying in close contact and encircling the white, starchy-looking *endosperm*.[1]

The name *endosperm* is applied to food stored in parts of the seed other than the embryo.[2] With a mounted needle pick out the little almost spherical mass of endosperm from inside the cotyledons of a seed which has been deprived of its coats, and sketch the embryo, noting how it is curved so as to enclose the endosperm almost completely.

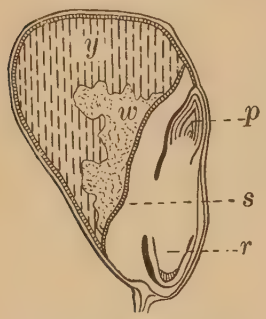


FIG. 6. — Lengthwise Section of Grain of Corn. (Magnified about three times.)

y, yellow, oily part of endosperm; *w*, white, starchy part of endosperm; *p*, plumule; *s*, the shield (cotyledon), in contact with the endosperm for absorption of food from it; *r*, the primary root.

19. Examination of the Kernel of Indian Corn. — Soak some grains of large yellow field corn[3] for about three days.

Sketch an unsoaked kernel, so as to show the grooved side, where the germ lies. Observe how this groove has become partially filled up in the soaked kernels.

Remove the thin, tough skin from one of the latter, and notice its transparency. This skin — the bran of unsifted corn meal — does not exactly correspond to the testa and inner coat of ordinary seeds, since the kernel of corn, like all other grains (and like the seed of the four-o'clock), represents not merely the seed, but also the seed-vessel in which it was formed and grew, and is therefore a fruit.

[1] Buckwheat furnishes another excellent study in seeds with endosperm. Like that of the four-o'clock, it is, strictly speaking, a fruit; so also is a grain of corn.

[2] In the squash seed the green layer which covered the embryo represents the endosperm. Reserve food derived from the part of the ovule (*nucellus*) just outside of the embryo sac (Fig. 165) is called *perisperm*.

[3] The varieties of "dent corn," with long, flat kernels, are the best.

Cut sections of the soaked kernels, some transverse, some lengthwise and parallel to the flat surfaces, some lengthwise and at right angles to the flat surfaces. Try the effect of staining some of these sections with iodine solution.

Make a sketch of one section of each of the three kinds, and label the dirty white portion, of cheesy consistency, *embryo;* and the yellow portions, and those which are white and floury, *endosperm.*

Chip off the endosperm from one kernel so as to remove the embryo free from other parts.[1] Notice its form, somewhat triangular in outline, sometimes nearly the shape of a beechnut, in other specimens nearly like an almond.

Estimate what proportion of the entire bulk of the soaked kernel is embryo.

Split the embryo lengthwise so as to show the slender, somewhat conical plumule.[2]

20. Corn Seedlings deprived of Endosperm. — An experiment parallel to No. V serves to show the function and the importance of the endosperm of Indian corn.

EXPERIMENT VII

Of how much Use to the Corn Seedling is the Endosperm ? — Sprout kernels of corn on blotting paper. When they get fairly started, cut away the endosperm carefully from several of the seeds. Suspend on mosquito netting on the surface of water in the same jar two or three seedlings which have had their endosperm removed, and as many which have not been mutilated. Let them grow for some weeks, and note results.

21. Starch. — Most common seeds contain starch. Every one knows something about the appearance of ordi-

[1] The embryo may be removed with great ease from kernels of rather mature green corn. Boil the corn for about twenty minutes on the cob, then pick the kernels off one by one with the point of a knife. They may be preserved indefinitely in alcohol of 50 or 75%.

[2] The teacher may well consult Figs. 56–61, inclusive, in Gray's *Structural Botany.*

nary commercial starch as used in the laundry, and as sold for food in packages of cornstarch. When pure it is characterized not only by its lustre, but also by its peculiar velvety feeling when rubbed between the fingers.

22. The Starch Test. — It is not always easy to recognize at sight the presence of starch as it occurs in seeds, but it may be detected by a very simple chemical test, namely, the addition of a solution of iodine.[1]

EXPERIMENT VIII[2]

Examination of Familiar Seeds with Iodine. — Cut in two with a sharp knife the seeds to be experimented on, then pour on each, drop by drop, some of the iodine solution. Only a little is necessary; sometimes the first drop is enough.

If starch is present, a blue color (sometimes almost black) will appear. If no color is obtained in this way, boil the pulverized seeds for a moment in a few drops of water, and try again.

Test in this manner corn, wheat (in the shape of flour), oats (in oatmeal), barley, rice, buckwheat, flax, rye, sunflower, four-o'clock, morning-glory, mustard seed, beans, peanuts, Brazil-nuts, hazelnuts, and any other seeds that you can get. Report your results in tabular form as follows:

Much Starch	Little Starch	No Starch
Color: blackish or dark blue.	Color: pale blue or greenish.	Color: brown, orange, or yellowish.

23. Microscopical Examination of Starch.[3] — Examine starch in water with a rather high power of the microscope (not less than 200 diameters).

[1] The tincture of iodine sold at the drug-stores will do, but the solution prepared as directed in the *Handbook* answers better. This may be made up in quantity, and issued to the pupils in drachm vials, to be taken home and used there, if the experimenting must be done outside of the laboratory or the schoolroom.

[2] May be a home experiment.

[3] At this point the teacher should give a brief illustrated talk on the construction and theory of the compound microscope.

Pulp scraped from a potato, that from a canna rootstock, wheat flour, the finely powdered starch sold under the commercial name of "cornstarch" for cooking, oatmeal, and buckwheat finely powdered in a mortar, will furnish excellent examples of the shape and markings of starch grains. Sketch all of the kinds examined, taking pains to bring out the markings.[1] Compare the sketches with Figs. 7 and 8.

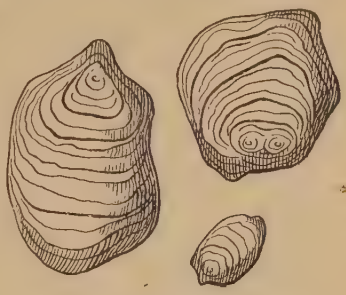


FIG. 7. — Canna Starch. (Magnified 300 diameters.)

With a medicine-dropper or a very small pipette run in a drop of iodine solution under one edge of the cover-glass, at the same time withdrawing a little water from the margin opposite by touching to it a bit of blotting paper.

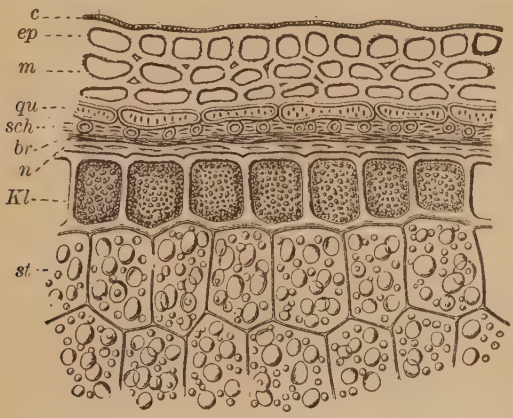


FIG. 8. — Section through Exterior Part of a Grain of Wheat.

c, cuticle or outer layer of bran; *ep*, epidermis; *m*, layer beneath epidermis; *qu*, *sch*, layers of hull next to seed-coats; *br*, *n*, seed-coats; *Kl*, layer containing proteid grains; *st*, cells of the endosperm filled with starch. (Greatly magnified.)

[1] The markings will be seen more distinctly if care is taken not to admit too much light to the object. Rotate the diaphragm beneath the stage of the microscope, or otherwise regulate the supply of light, until the opening is found which gives the best effect.

Examine again and note the blue coloration of the starch grains and the unstained or yellow appearance of other substances in the field. Cut very thin slices from beans, peas, or kernels of corn; mount in water, stain as above directed, and draw as seen under the microscope. Compare with Figs. 7 and 8.[1] Note the fact that the starch is not packed away in the seeds in bulk, but that it is enclosed in little chambers or *cells*.

24. Plant-Cells. — Almost all the parts of the higher plants are built up of little separate portions called *cells*. The cell is the unit of plant-structure, and bears something the same relation to the plant of which it is a part that one cell of a honeycomb does to the whole comb. But this comparison is not a perfect one, for neither the waxen wall of the honeycomb-cell nor the honey within it is alive, while every plant-cell is or has been alive. And even the largest ordinary honeycomb consists of only a few hundred cells, while a large tree is made up of very many millions of cells. The student must not conceive of the cell as merely a little chamber or enclosure. *The living, more or less liquid, or mucilage-like, or jelly-like substance known as protoplasm, which forms a large portion of the bulk of living and growing cells, is the all-important part of such a cell.* Professor Huxley has well called this substance "the physical basis of life." Cells are of all shapes and sizes, from little spheres a ten-thousandth of an inch or less in diameter to slender tubes, such as fibers of cotton, several inches long. To get an idea of the appearance of some rather large cells, scrape a little pulp from a ripe, mealy apple, and examine it first with

[1] The differentiation between the starch grains, the other cell-contents, and the cell-walls will appear better in the drawings if the starch grains are sketched with blue ink.

a strong magnifying glass, then with a moderate power of the compound microscope. To see how dead, dry cell-walls, with nothing inside them, look, examine (as before) a very thin slice of elder pith, sunflower pith, or pith from a dead cornstalk. Look also at the figures in Chapter VI of this book. Notice that the simplest plants (Chapter XX) consist of a single cell each. The study of the structure of plants is the study of the forms which cells and groups of cells assume, and the study of plant physiology is the study of what cells and cell combinations do.

25. Absorption of Starch from the Cotyledons. — Examine with the microscope, using a medium power, soaked beans and the cotyledons from seedlings that have been growing for three or four weeks. Stain the sections with iodine solution, and notice how completely the clusters of starch grains that filled most of the cells of the unsprouted cotyledons have disappeared from the shriveled cotyledons of the seedlings. A few grains may be left, but they have lost their sharpness of outline.

26. Oil. — The presence of oil in any considerable quantity in seeds is not as general as is the presence of starch, though in many common seeds there is a good deal of it.

Sometimes the oil is sufficiently abundant to make it worth while to extract it by pressure, as is done with flax-seed, cotton-seed, the seeds of some plants of the cress family, the "castor bean," and other seeds.

27. Dissolving Oil from Ground Seeds. — It is not possible easily to show a class how oil is extracted from seeds by pressure; but there are several liquids which readily dissolve oils and yet have no effect on starch and most of the other constituents of seeds.

EXPERIMENT IX

Extraction of Oil by Ether or Benzine. — To a few ounces of ground flaxseed add an equal volume of ether or benzine. Let it stand ten or fifteen minutes and then filter. Let the liquid stand in a saucer or evaporating dish in a good draught till it has lost the odor of the ether or benzine.

Describe the oil which you have obtained.

Of what use would it have been to the plant?

If the student wishes to do this experiment at home for himself, he should bear in mind the following:

Caution. — Never handle benzine or ether near a flame or stove.

A much simpler experiment to find oil in seeds may readily be performed by the pupil at home. Put the material to be studied, *e.g.*, flaxseed meal, corn meal, wheat flour, cotton-seed meal, buckwheat flour, oatmeal, and so on, upon little labeled pieces of white paper, one kind of flour or meal on each bit of paper. Place all the papers, with their contents, on a perfectly clean plate, free from cracks, or on a clean sheet of iron, and put this in an oven hot enough nearly (but not quite) to scorch the paper. After half an hour remove the plate from the oven, shake off the flour or meal from each paper, and note the results, a more or less distinct grease spot showing the presence of oil, or the absence of any stain that there was little or no oil in the seed examined.

28. Albuminous Substances. — Albuminous substances or *proteids* occur in all seeds, though often only in small quantities. They have nearly the same chemical composition as white of egg and the curd of milk among animal substances, and are essential to the plant, since the living and growing parts of all plants contain large quantities of proteid material.

Sometimes the albuminous constituents of the seed occur in more or less regular grains (Fig. 8, at *Kl*).

But much of the proteid material of seeds is not in any

form in which it can be recognized under the microscope. One test for its presence is the peculiar smell which it produces in burning. Hair, wool, feathers, leather, and lean meat all produce a well-known sickening smell when scorched or burned, and the similarity of the proteid material in such seeds as the bean and pea to these substances is shown by the fact that scorching beans and similar seeds give off the familiar smell of burnt feathers.

29. Chemical Tests for Proteids. — All proteids (and very few other substances) are turned yellow by nitric acid, and this yellow color becomes deeper or even orange when the yellowish substance is moistened with ammonia. They are also turned yellow by iodine solution. Most proteids are turned more or less red by the solution of nitrate of mercury known as Millon's reagent.[1]

EXPERIMENT X

Detection of Proteids in Seeds. — Extract the germs from some soaked kernels of corn and bruise them; soak some wheat-germ meal for a few hours in warm water, or wash the starch out of wheat-flour dough; reserving the latter for use, place it in a white saucer or porcelain evaporating dish, and moisten well with Millon's reagent or with nitric acid; examine after fifteen minutes.

30. The Brazil-Nut as a Typical Oily Seed. — Not many familiar seeds are as oily as the Brazil-nut. Its large size makes it convenient for examination, and the fact that this nut is good for human food makes it the more interesting to investigate the kinds of plant-food which it contains.

[1] See *Handbook*.

EXPERIMENT XI

Testing Brazil-Nuts for Plant-Foods. — Crack fifteen or twenty Brazil-nuts, peel off the brown coating from the kernel of each, and then grind the kernels to a pulp in a mortar. Shake up this pulp with ether, pour upon a paper filter, and wash with ether until the washings when evaporated are nearly free from oil. The funnel containing the filter should be kept covered as much as possible until the washing is finished. Evaporate the filtrate to procure the oil, which may afterwards be kept in a glass-stoppered bottle. Dry the powder which remains on the filter and keep it in a wide-mouthed bottle. Test portions of this powder for proteids and for starch. Explain the results obtained.

31. Other Constituents of Seeds. — Besides the substances above suggested, others occur in different seeds. Some of these are of use in feeding the seedling, others are of value in protecting the seed itself from being eaten by animals or in rendering it less liable to decay. In such seeds as that of the nutmeg, the essential oil which gives it its characteristic flavor probably makes it unpalatable to animals and at the same time preserves it from decay.

Date seeds are so hard and tough that they cannot be eaten and do not readily decay. Lemon, orange, horse-chestnut and buckeye seeds are too bitter to be eaten, and the seeds of the apple, cherry, peach, and plum are somewhat bitter.

The seeds of larkspur, thorn-apple,[1] croton, the castor-oil plant, nux vomica, and many other kinds of plants contain active poisons.

[1] Datura, commonly called "Jimpson weed."

CHAPTER III

MOVEMENTS, DEVELOPMENT, AND MORPHOLOGY OF THE SEEDLING

32. How the Seedling breaks Ground. — As the student has already learned by his own observations, the seedling does not always push its way straight out of the ground. Corn, like all the other grains and grasses, it is true, sends a tightly rolled, pointed leaf vertically upward into the air. But the other seedlings examined usually will not be found to do anything of the sort. The squash seedling is a good one in which to study what may be called the arched hypocotyl type of germination. If the seed when planted is laid horizontally on one of its broad surfaces, it usually goes through some such changes of position as are shown in Fig. 9.

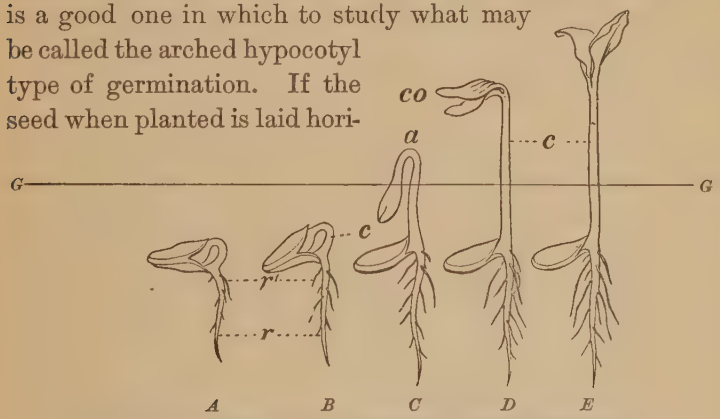


FIG. 9. — Successive Stages in the Life History of the Squash Seedling.

GG, the surface of the ground; *r*, primary root; *r'*, secondary root; *c*, hypocotyl; *a*, arch of hypocotyl; *co*, cotyledons.

The seed is gradually tilted until, at the time of their emergence from the ground (at *C*), the cotyledons are almost vertical. The only part above the ground-line *G*, *G*, at this period, is the arched hypocotyl. Once out of ground, the cotyledons soon rise, until (at *E*) they are again vertical, but with the other end up from that which stood highest in *C*. Then the two cotyledons separate until they once more lie horizontal, pointing away from each other.

Can you suggest any advantage which the plant derives from having the cotyledons dragged out of the ground rather than having them pushed out, tips first?

33. Cause of the Arch. — It is evident that a flexible object like the hypocotyl, when pushed upward through the earth, might easily be bent into an arch or loop. Whether the shape which the hypocotyl assumes is wholly caused by the resistance of the soil can best be ascertained by an experiment.

EXPERIMENT XII

Is the Arch of the Hypocotyl due to the Pressure of the Soil on the Rising Cotyledons? — Sprout some squash seeds on wet paper under a bell-glass, and when the root is an inch or more long, hang several of the seedlings, roots down, in little stirrups made of soft twine, attached by beeswax and rosin mixture to the inside of the upper part of a bell-glass. Put the bell-glass on a large plate or a sheet of glass on which lies wet paper to keep the air moist. Note whether the seedlings form hypocotyl arches at all and, if so, whether the arch is more or less perfect than that formed by seedlings growing in earth, sand, or sawdust.

34. What pushes the Cotyledons up? — A very little study of any set of squash seedlings, or even of Fig. 9, is

sufficient to show that the portion of the plant where roots and hypocotyl are joined neither rises nor sinks, but that the plant grows both ways from this part (a little above r' in Fig. 9, *A* and *B*). It is evident that as soon as the hypocotyl begins to lengthen much it must do one of two things: either push the cotyledons out into the air or else force the root down into the ground as one might push a stake down. What changes does the plantlet undergo, in passing from the stage shown at *A* to that of *B* and of *C*, making it harder and harder for the root to be thrust downward?

35. Use of the Peg. — Squash seedlings usually (though not always) form a sort of knob on the hypocotyl. This is known as the peg. Study a good many seedlings and try to find out what the lengthening of the hypocotyl, between the peg and the bases of the cotyledons, does for the little plant. Set a lot of squash seeds, hilum down, in moist sand or sawdust and see whether the peg is more or less developed than in seeds sprouted lying on their sides, and whether the cotyledons in the case of the vertically planted seeds usually come out of the ground in the same condition as do those shown in Fig. 9.

36. Discrimination between Root and Hypocotyl. — It is not always easy to decide by their appearance and behavior what part of the seedling is root and what part is hypocotyl. In a seedling visibly beginning to germinate, the sprout, as it is commonly called, which projects from the seed might be either root or hypocotyl or might consist of both together, so far as its appearance is concerned. A microscopic study of the cross-section of a root, compared with one of the hypocotyl, would show decided differences

of structure between the two. Their mode of growth is also different, as the pupil may infer after he has tried Exp. XIV.

37. Discrimination by Staining. — For some reason, perhaps because the skin or epidermis of the young root is not so water-proof as that of the stem, the former stains more easily than the latter does.

EXPERIMENT XIII

The Permanganate Test. — Make a solution of potassium permanganate in water, by adding about four parts, by weight, of the crystallized permanganate to 100 parts of water. Drop into the solution seedlings, *e.g.*, of all the kinds that have been so far studied, each in its earliest stage of germination (that is, when the root or hypocotyl has pushed out of the seed half an inch or less), and also at one or two subsequent stages. After the seedlings have been in the solution from three to five minutes, or as soon as the roots are considerably stained, pour off (and save) the solution and rinse the plants with plenty of clear water. Sketch one specimen of each kind, coloring the brown-stained part, which is root, in some way so as to distinguish it from the unstained hypocotyl. Note particularly how much difference there is in the amount of lengthening in the several kinds of hypocotyl examined. Decide whether the peg of the squash seedling is an outgrowth of hypocotyl or of root.

38. Disposition made of the Cotyledons. — As soon as the young plants of squash, bean, and pea have reached a height of three or four inches above the ground it is easy to recognize important differences in the way in which they set out in life.

The cotyledons of the squash increase greatly in surface, acquire a green color and a generally leaf-like appearance, and, in fact, do the work of ordinary leaves. In

such a case as this the appropriateness of the name *seed-leaf* is evident enough, — one recognizes at sight the fact that the cotyledons are actually the plant's first leaves. In the bean the leaf-like nature of the cotyledons is not so clear. They rise out of the ground like the squash cotyledons, but then gradually shrivel away, though they may first turn green and somewhat leaf-like for a time.

In the pea (as in the acorn, the horse-chestnut, and many other seeds) we have quite another plan, the underground type of germination. Here the thick cotyledons no longer rise above ground at all, because they are so gorged with food that they could never become leaves; but the young stem pushes rapidly up from the surface of the soil.

The development of the plumule seems to depend somewhat on that of the cotyledons. The squash seed has cotyledons which are not too thick to become useful leaves, and so the plant is in no special haste to get ready any other leaves. The plumule, therefore, cannot be found with the magnifying glass in the unsprouted seed, and is almost microscopic in size at the time when the hypocotyl begins to show outside of the seed-coats.

In the bean and pea, on the other hand, since the cotyledons cannot serve as foliage leaves, the later leaves must be pushed forward rapidly. In the bean the first pair are already well formed in the seed. In the pea they cannot be clearly made out, since the young plant forms several scales on its stem before it produces any full-sized leaves, and the embryo contains only hypocotyl, cotyledons, and a sort of knobbed plumule, well developed in point of size, representing the lower scaly part of the stem.

39. Root, Stem, and Leaf. — By the time the seedling is well out of the ground it, in most cases, possesses the three kinds of *vegetative organs*, or parts essential to growth, of ordinary flowering plants, *i.e.*, the root, stem, and leaf, or, as they are sometimes classified, root and shoot. All of these organs may multiply and increase in size as the plant grows older, and their mature structure will be studied in later chapters, but some facts concerning them can best be learned by watching their growth from the outset.

40. Young Roots grown for Examination. — Roots growing in sand or ordinary soil cling to its particles so tenaciously that they cannot easily be studied, and those grown in water have not quite the same form as soil-roots. Roots grown in damp air are best adapted for careful study.

41. Elongation of the Root. — We know that the roots of seedlings grow pretty rapidly from the fact that each day finds them reaching visibly farther down into the water or other medium in which they are planted. A sprouted Windsor bean in a vertical thistle-tube will send its root downward fast enough so that ten minutes' watching through the microscope will suffice to show growth. To find out just where the growth goes on requires a special experiment.

EXPERIMENT XIV

In what Portions of the Root does its Increase in Length take Place? — Sprout some peas on moist blotting paper in a loosely covered tumbler. When the roots are one and a half inches or more long, mark them along the whole length with little dots made with a bristle dipped in water-proof India ink, or a fine inked thread stretched on a little bow of whalebone or brass wire.

Transfer the plants to moist blotting paper under a bell-glass or an inverted battery jar and examine the roots at the end of twenty-four hours to see along what portions their length has increased; continue observations on them for several days.

42. Root-Hairs. — Barley, oats, wheat, red clover, or buckwheat seeds soaked and then sprouted on moist blotting paper afford convenient material for studying *root-hairs*. The seeds may be kept covered with a watch-glass or a clock-glass while sprouting. After they have begun to germinate well, care must be taken not to have them kept in too moist an atmosphere, or very few root-hairs will be formed. Examine with the magnifying glass those parts of the root which have these appendages.

Try to find out whether all the portions of the root are equally covered with hairs and, if not, where they are most abundant. (See also Sect. 53.)

The root-hairs in plants growing under ordinary conditions are surrounded by the moist soil and wrap themselves around microscopical particles of earth (Fig. 11). Thus they are able rapidly to absorb through their thin walls the soil-water, with whatever mineral substances it has dissolved in it.

43. The Young Stem. — The hypocotyl, or portion of the stem which lies below the cotyledons, is the earliest formed portion of the stem. Sometimes this lengthens but little; often, however, as the student knows from his own observations, the hypocotyl lengthens enough to raise the cotyledons well above ground, as in Fig. 10.

The later portions of the stem are considered to be divided into successive *nodes*, — places at which a leaf (or

a scale which represents a leaf) appears; and *internodes*,— portions between the leaves.

The student should watch the growth of a seedling bean or pea and ascertain by actual measurements whether the internodes lengthen after they have once been formed. and if so, for how long a time the increase continues.

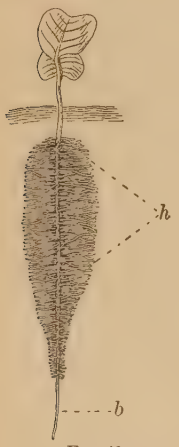


FIG. 10.

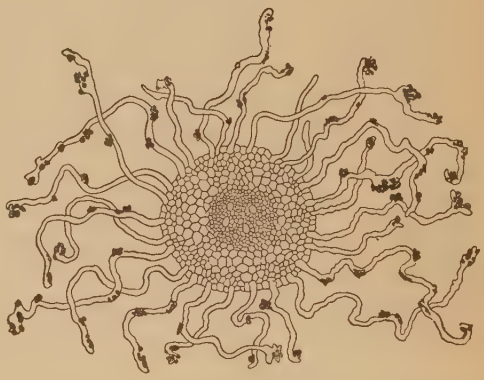


FIG. 11.

FIG. 10. — A Turnip Seedling, with the Cotyledons developed into Temporary Leaves. *h*, root-hairs from the primary root; *b*, bare portion of the root, on which no hairs have as yet been produced.

FIG. 11. — Cross-Section of a Root, a good deal magnified, showing root-hairs attached to particles of soil, and sometimes enwrapping these particles.

44. The First Leaves. — The cotyledons are, as already explained, the first leaves which the seedling possesses, — even if a plumule is found well developed in the seed, it was formed after the cotyledons. In those plants which have so much food stored in the cotyledons as to render these unfit ever to become useful foliage leaves, there is little or nothing in the color, shape, or general appearance

of the cotyledon to make one think it really a leaf, and it is only by studying many cases that the botanist is enabled to class all cotyledons as leaves in their nature, even if they are quite unable to do the ordinary work of leaves. The study of the various forms which the parts or organs of a plant may assume is called *morphology;* it traces the relationship of parts which are really akin to each other, though dissimilar in appearance and often in function. In seeds which have *endosperm*, or food stored outside of the embryo, the cotyledons usually become green and leaf-like, as they do, for example, in the four-o'clock, the morning-glory, and the buckwheat; but in the seeds of the grains (which contain endosperm) a large portion of the single cotyledon remains throughout as a thickish mass buried in the seed. In a few cases, as in the pea, there are scales instead of true leaves formed on the first nodes above the cotyledons, and it is only at about the third node above that leaves of the ordinary kind appear. In the bean and some other plants which in general bear one leaf at a node along the stem, there is a pair produced at the first node above the cotyledons, and the leaves of this pair differ in shape from those which arise from the succeeding portions of the stem.

FIG. 12. — Germinating Pine. *co*, cotyledons.

45. Classification of Plants by the Number of their Cotyledons. — In the pine family the germinating seed often displays more than two cotyledons, as shown in Fig. 12; in the majority of common flowering plants the seed contains two cotyledons, while in the lilies, the rushes, the

sedges, the grasses, and some other plants, there is but one cotyledon. Upon these facts is based the division of most flowering plants into two great groups: the *dicotyledonous plants*, which have two seed-leaves, and the *monocotyledonous plants*, which have one seed-leaf. Other important differences nearly always accompany the difference in number of cotyledons, as will be seen later.

46. Tabular Review of Experiments. — Make out a table containing a very brief summary of the experiments thus far performed, as follows:

Number of Experiment	Object sought	Materials and Apparatus	Operations performed	Results	Inferences

47. Review Sketches. — Make out a comparison of the early life histories of all the other seedlings studied, by arranging in parallel columns a series of drawings of each,

like those of Fig. 9, but in vertical series, the youngest of each at the top, thus:

	Bean	Pea	Corn
First Stage			
Second Stage			
Third Stage			
Fourth Stage			
Fifth Stage etc.			

CHAPTER IV

ROOTS [1]

48. Origin of Roots. — The *primary root* originates from the lower end of the hypocotyl, as the student learned from his own observations on sprouting seeds. The branches of the primary root are called *secondary roots*, and the branches of these are known as *tertiary roots*. Those roots which occur on the stem or in other unusual places are known as *adventitious roots*. The roots which form so readily on cuttings of willow, southernwood, tropæolum, French marigold, geranium (pelargonium), tradescantia, and many other plants, when placed in damp earth or water, are adventitious.

49. Aerial Roots. — While the roots of most familiar plants grow in the earth and are known as *soil-roots*, there are others which are formed in the air, called *aerial roots*. They serve various purposes: in some tropical air-plants (Fig. 13) they serve to fasten the plant to the tree on which it establishes itself, as well as to take in water which drips from branches and trunks above them, so that these plants require no soil and grow in mid-air suspended from trees, which serve them merely as supports ; [2] many such

[1] To the plant the root is more important than the stem. The author has, however, treated the structure of the latter more fully than that of the root, mainly because the tissues are more varied in the stem and a moderate knowledge of the more complex anatomy of the stem will serve every purpose.

[2] If it can be conveniently managed, the class will find it highly interesting and profitable to visit any greenhouse of considerable size, in which the aerial roots of orchids and aroids may be examined.

air-plants are grown in greenhouses. In such plants as the ivy (Fig. 15) the aerial roots (which are also adventitious) hold the plant to the wall or other surface up which it climbs.

In the Indian corn (Fig. 14) roots are sent out from nodes at some distance above the ground and finally descend until they enter the ground. They serve both to anchor the cornstalk so as to enable it to resist the wind and to supply additional water to the plant.[1] They often produce no rootlets until they reach the ground.

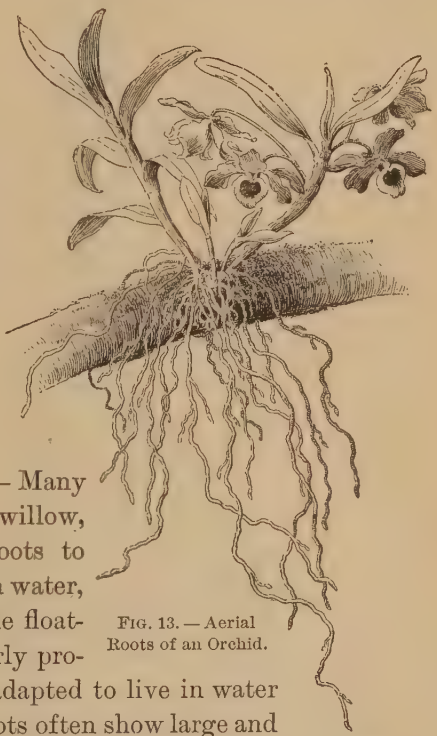


FIG. 13. — Aerial Roots of an Orchid.

50. Water-Roots. — Many plants, such as the willow, readily adapt their roots to live either in earth or in water, and some, like the little floating duckweed, regularly produce roots which are adapted to live in water only. These water-roots often show large and distinct sheaths on the ends of the roots, as, for instance, in the so-called water-hyacinth. This plant is especially interesting for laboratory cultivation from the fact that

[1] Specimens of the lower part of the cornstalk, with ordinary roots and aerial roots, should be dried and kept for class study.

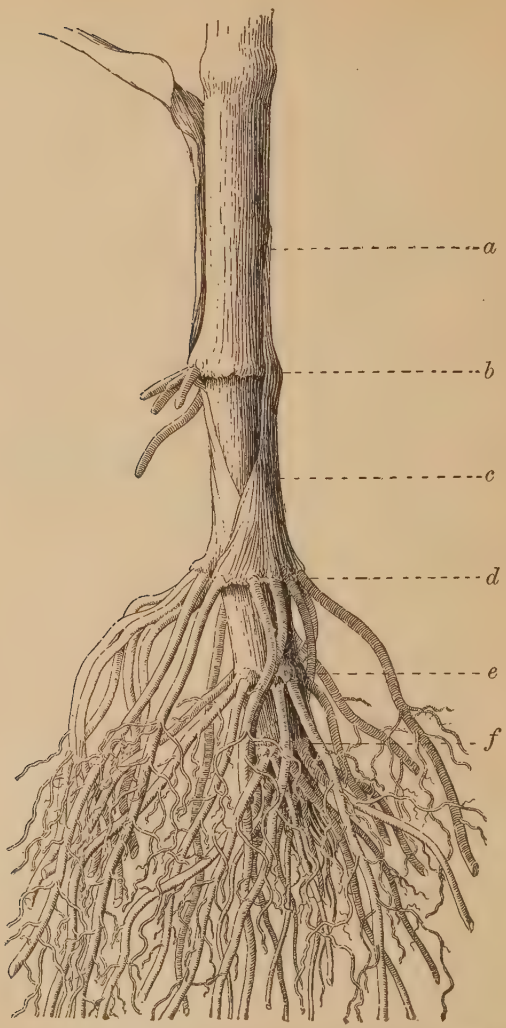


FIG. 14. — Lower Part of Stem and Roots of Indian Corn, showing Aerial Roots ("Brace-Roots").

a, *c*, internodes of the stem; *b*, *d*, *e*, *f*, nodes of various age bearing roots. Most of these started as aerial roots, but all except those from *b* have now reached the earth.

it may readily be transferred to moderately damp soil, and that the whole plant presents curious modifications when made to grow in earth instead of water.

51. Parasitic Roots.[1] — The dodder, the mistletoe, and a good many other *parasites*, live upon nourishment which they steal from other plants, called *hosts*. The parasitic

FIG. 15. — Aerial Adventitious Roots of the Ivy.

roots, or *haustoria*, form the most intimate connections with the interior portions of the stem or the root, as the case may be, of the host-plant on which the parasite fastens itself.

In the dodder, as is shown in Fig. 16, it is most interesting to notice how admirably the seedling parasite is adapted to the conditions under which it is to live. Rooted

[1] See Kerner and Oliver's *Natural History of Plants*, Vol. I, pp. 171–213.

at first in the ground, it develops a slender, leafless stem, which, leaning this way and that, no sooner comes into

FIG. 16. — Dodder, growing upon a Golden-Rod Stem.

s, seedling dodder plants, growing in earth; *h*, stem of host; *r*, haustoria or parasitic roots of dodder; *l*, scale-like leaves. *A*, magnified section of a portion of willow stem, showing penetration of haustoria.

permanent contact with a congenial host than it produces haustoria at many points, gives up further growth in its

soil-roots, and grows rapidly on the strength of the supplies of ready-made sap which it obtains from the host.

52. Forms of Roots. — The primary root is that which proceeds like a downward prolongation directly from the lower end of the hypocotyl. In many cases the mature root-system of the plant contains one main root much larger than any of its branches. This is called a *taproot* (Fig. 17).

Such a root, if much thickened, would assume the form

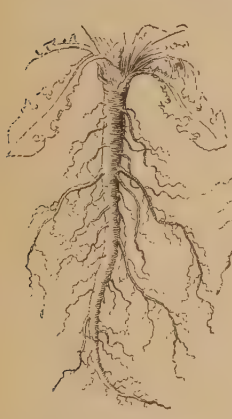


FIG. 17. — A Taproot.

FIG. 18. — Fibrous Roots.

FIG. 19. — Fascicled Roots.

shown in the carrot, parsnip, beet, turnip, salsify, or radish, and is called a fleshy root. Some plants produce *multiple primary* roots, that is, a cluster proceeding from the lower end of the hypocotyl at the outset. If such roots become thickened, like those of the sweet potato and the dahlia (Fig. 19), they are known as *fascicled roots.*

Roots of grasses, etc., are thread-like, and known as *fibrous roots* (Fig. 18).

53. General Structure of Roots. — The structure of the very young root can be partially made out by examining

the entire root with a moderate magnifying power, since the whole is sufficiently translucent to allow the interior as well as the exterior portion to be studied while the root is still alive and growing.

Place some vigorous cuttings of tradescantia or *Zebrina*, which can usually be obtained of a gardener or florist, in a beaker or jar of water.[1] The jar should be as thin and transparent as possible, and it is well to get a flat-sided rather than a cylindrical one. Leave the jar of cuttings in a sunny, warm place. As soon as roots have developed at the nodes and reached the length of three-quarters of an inch or more, arrange a microscope in a horizontal position (see *Handbook*), and examine the tip and adjacent portion of one of the young roots with a power of from twelve to twenty diameters.

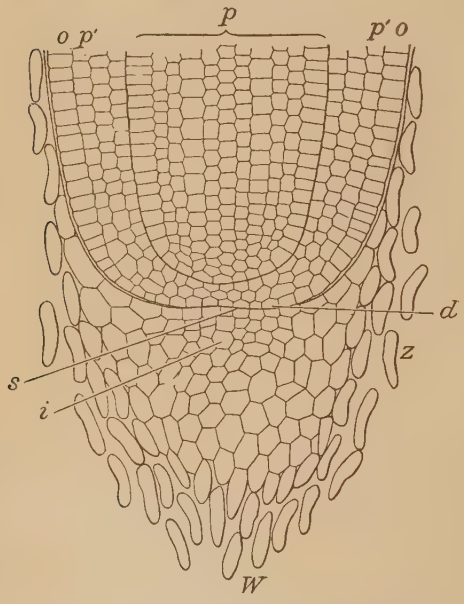


FIG. 20. — Lengthwise Section (somewhat diagrammatic) through Root-Tip of Indian Corn. × about 130.

W, root-cap; *i*, younger part of cap; *z*, dead cells separating from cap; *s*, growing point; *o*, epidermis; *p'*, intermediate layer between epidermis and central cylinder; *p*, central cylinder; *d*, layer from which the root-cap originates.

Note:

(*a*) The root-cap, of loosely attached cells.

(*b*) The central cylinder.

[1] If the tradescantia or *Zebrina* cannot be obtained, roots of seedlings of oats, wheat, or barley, or of red-clover seedlings raised in a large covered cell on a microscope slide, may be used.

(*c*) The cortical portion, a tubular part enclosing the solid central cylinder.

(*d*) The root-hairs, which cover some parts of the outer layer of the cortical portion very thickly. Observe particularly how far toward the tip of the root the root-hairs extend, and where the youngest ones are found.

Make a drawing to illustrate all the points above suggested (*a*, *b*, *c*, *d*). Compare your drawing with Fig. 20. Make a careful study of longitudinal sections through the centers of the tips of very young roots of the hyacinth or the Chinese sacred lily. Sketch one section and compare the sketch with Fig. 20.

Make a study of the roots of any of the common duckweeds, growing in nutrient solution in a jar of water under a bell-glass, and note the curious root-pockets which here take the place of root-caps.

54. Details of Root-Structure. — The plan on which the young root is built has been outlined in Sect. 53. A few further particulars are necessary to an understanding of how the root does its work. On examining Fig. 21 the cylinders of which the root is made up are easily distinguished, and the main constituent parts of each can be made out without much trouble. The epidermis-cells are seen to be somewhat brick-shaped, many of them provided with extensions into root-hairs. Inside the epidermis lie several layers of rather globular, thin-walled cells, and inside these a boundary layer between the cortical or bark portion of the root and the central cylinder. This latter region is especially marked by the presence of certain groups of cells, shown at *w* and *d* and at *b*, the two former serving as channels for air and water, the latter (and *w* also) giving toughness to the root.

Roots of shrubs and trees more than a year old will be found to have increased in thickness by the process

described in Sect. 106, and a section may look quite unlike the young root-section shown in Fig. 21.

55. Examination of the Root of a Shrub or Tree. — Cut thin transverse sections of large and small roots of any hardwood tree[1] and examine them first with a low power of the microscope, as a two-inch objective, to get the general disposition of the parts, then with a higher power, as the half-inch or quarter-inch, for details. With the low power, note:

(*a*) The brown layer of outer bark.

(*b*) The paler layer within this.

(*c*) The woody cylinder which forms the central portion of the root.

The distinction between (*b*) and (*c*) is more evident when the section has been exposed to the air for a few minutes and changed somewhat in color. It is a good plan to look with the low power first at a thick section, viewed as an opaque object, and then at a very thin one mounted in water or glycerine, and viewed as a transparent object.

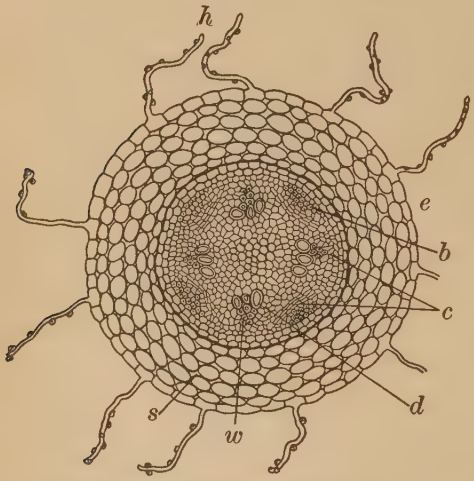


FIG. 21. — Much Magnified Cross-Section of a Very Young Dicotyledonous Root.

h, root-hairs with adhering bits of sand; *e*, epidermis; *s*, thin-walled, nearly globular cells of bark; *b*, hard bast; *c*, cambium; *w*, wood-cells; *d*, ducts.

Observe the cut-off ends of the *ducts*, or *vessels*, which serve as passages for air and water to travel through; these appear as holes in the section, and are much more abundant relatively in the young

[1] Young suckers of cherry, apple, etc., which may be pulled up by the roots, will afford excellent material.

than in the older and larger portions of the root. Sketch one section of each kind.

Examine with a higher power (100 to 200 diameters), and note the ends of the thick-walled wood-cells. Compare these with Fig. 72.

Notice the many thinner-walled cells composing stripes radiating away from the center of the root. These bands are the *medullary rays*, whose mode of origin is shown in Fig. 68. Moisten some of the sections with iodine solution,[1] and note where the blue color shows the presence of starch. Split some portions of the root through the middle, cut thin sections from the split surface, and examine with the high power some unstained and some stained with iodine.

Notice the appearance of the wood-cells and the ducts as seen in these sections, and compare with Fig. 58.[2]

56. Structure and Contents of a Fleshy Root. — In some fleshy roots, such as the beet, the morphology of the parts is rather puzzling, since they form many layers of tissue in a single season, showing on the cross-section of the root a series of layers which look a little like the annual rings of trees.

The structure of the turnip, radish, carrot, and parsnip is simpler.

Cut a parsnip across a good deal below the middle, and stand the cut end in eosin solution for twenty-four hours.

Then examine by slicing off successive portions from the upper end. Sketch some of the sections thus made. Cut one parsnip lengthwise and sketch the section obtained. In what portion of the root did the colored liquid rise most readily? The ring of red marks the boundary between the cortical portion and the central cylinder. To which does the main bulk of the parsnip belong? Cut thin transverse sections from an ink-stained parsnip and notice how the medullary rays run out into the cortical portion, and in those sections

[1] If the roots are in their winter condition.

[2] The examination of the minute structure of the root is purposely made very hasty, since the detailed study of the structural elements can be made to better advantage in the stem.

that show it, find out where the secondary roots arise. If possible, peel off the cortical portion from one stained root and leave the central cylinder with the secondary roots attached. Stain one section with iodine, and sketch it. Where is the starch of this root mainly stored?

Test some bits of parsnip for proteids, by boiling them for a minute or two with strong nitric acid.

What kind of plant-food does the taste of cooked parsnips show them to contain? [On no account taste the bits which have been boiled in the poisonous nitric acid.]

57. Storage in Other Roots. — The parsnip is by no means a remarkable plant in its capacity for root-storage. The roots of the yam and the sweet potato contain a good deal of sugar and much more starch than is found in the parsnip. Beet-roots contain so much sugar that a large part of the sugar supply of Europe and an increasing portion of our own supply is obtained from them. Oftentimes the bulk of a fleshy root is exceedingly large as compared with that of the parts of the plant above ground.

The South African plant (*Harpagophytum*, Chapter XXIV) is a good example of this, and another instance is that of a plant,[1] related to the morning-glory and the sweet potato, found in the southeastern United States, which has a root of forty or fifty pounds weight.

Not infrequently roots have a bitter or nauseous taste, as in the case of the chicory, the dandelion, and the rhubarb, and a good many, like the monkshood, the yellow jasmine, and the pinkroot, are poisonous. Can you give any reason why the plant may be benefited by the disgusting taste or poisonous nature of its roots?

[1] *Ipomœa Jalapa.*

58. Use of the Food stored in Fleshy Roots. — The parsnip, beet, carrot, and turnip are *biennial plants;* that is, they do not produce seed until the second summer or fall after they are planted.

The first season's work consists mainly in producing the food which is stored in the roots. To such storage is due their characteristic fleshy appearance. If this root is planted in the following spring, it feeds the rapidly growing stem which proceeds from the bud at its summit, and an abundant crop of flowers and seed soon follows; while the root, if examined in late summer, will be found to be withered, with its store of reserve material quite exhausted.

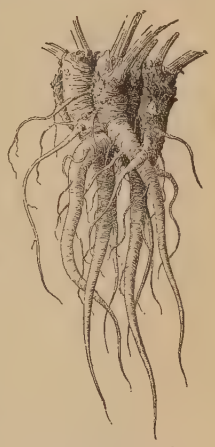


FIG. 22. — Fleshy Roots of Garden Rhubarb. (About one-fifteenth natural size.)

The roots of the rhubarb (Fig. 22), the sweet potato, and of a multitude of other *perennials*, or plants which live for many years, contain much stored plant-food. Many such plants die to the ground at the beginning of winter, and in spring make a rapid growth from the materials laid up in the roots.

59. Extent of the Root-System. — The total length of the roots of ordinary plants is much greater than is usually supposed. They are so closely packed in the earth that only a few of the roots are seen at a time during the process of transplanting, and when a plant is pulled or dug up in the ordinary way, a large part of the whole mass of roots is broken off and left behind. A few plants have

been carefully studied to ascertain the total weight and length of the roots. Those of winter wheat have been found to extend to a depth of seven feet. By weighing the whole root-system of a plant and then weighing a known length of a root of average diameter, the total length of the roots may be estimated. In this way the roots of an oat plant have been calculated to measure about 154 feet; that is, all the roots, if cut off and strung together end to end, would reach that distance.

Single roots of large trees often extend horizontally to great distances, but it is not often possible readily to trace the entire depth to which they extend. One of the most notable examples of an enormously developed root-system is found in the mesquite of the far Southwest and Mexico. When this plant grows as a shrub, reaching the height, even in old age, of only two or three feet, it is because the water supply in the soil is very scanty. In such cases the roots extend down to a depth of sixty feet or more, until they reach water, and the Mexican farmers in digging wells follow these roots as guides. Where water is more plenty, the mesquite forms a good-sized tree, with much less remarkably developed roots.

60. The Absorbing Surface of Roots. — Such aerial roots as are shown in Fig. 13 are usually covered with a spongy absorbent layer, by means of which they retain large quantities of the water which trickles down them during rain-storms. This water they afterwards gradually give up to the plant. Most water-roots (not however those of tradescantia) have no special arrangement for absorbing water except through the general surface of their epidermis. But some water-roots and most soil-roots take in water

mainly through the *root-hairs*. These are delicate, hair-like outgrowths from the epidermis of the root. They are, as seen in Fig. 11, thin-walled tubes, of nearly uniform diameter, closed at the outer end and opening at the inner end into the epidermis-cell from which they spring. The relation of each hair to the epidermis-cell is still better shown in Fig. 23, which represents a very young root-hair and a considerably older one.

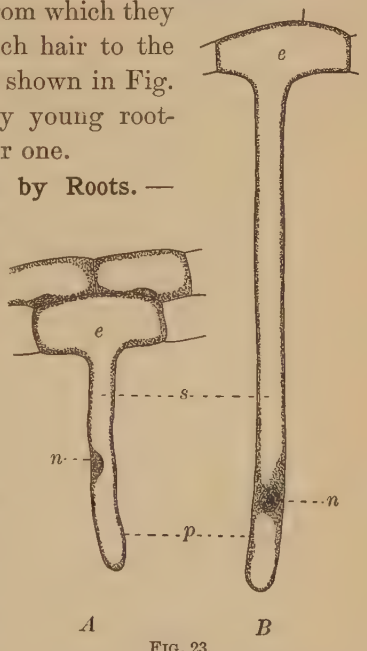


FIG. 23.

A, a very young root-hair; *B*, a much older one (both greatly magnified). *e*, cells of the epidermis of the root; *n*, nucleus; *s*, watery cell-sap; *p*, thicker protoplasm, lining the cell-wall.

61. Absorption of Water by Roots. — Many experiments on the cultivation of corn, wheat, oats, beans, peas, and other familiar plants in water have proved that some plants, at any rate, can thrive very well on ordinary lake, river, or well water, together with the food which they absorb from the air (Chapter XII). Just how much water some kinds of plants give off (and therefore absorb) per day will be discussed when the uses of the leaf are studied. For the present it is sufficient to state that even an annual plant during its lifetime absorbs through the roots very many times its own weight of water. Grasses have been known to take in their weight of water in every twenty-four hours of warm, dry weather. This absorption takes

place mainly through the root-hairs, which the student has examined as they occur in the seedling plant, and which are found thickly clothing the younger and more rapidly growing parts of the roots of mature plants. Some idea of their abundance may be gathered from the fact that on a rootlet of corn grown in a damp atmosphere, and about one-seventeenth of an inch in diameter, 480 root-hairs have been counted on each hundredth of an inch of root. The walls of the root-hairs are extremely thin, and they have no holes or pores visible under even the highest power of the microscope, yet the water of the soil penetrates very rapidly to the interior of the root-hairs. The soil-water brings with it all the substances which it can dissolve from the earth about the plant; and the closeness with which the root-hairs cling to the particles of soil, as shown in Figs. 11 and 21, must cause the water which is absorbed to contain more foreign matter than underground water in general does, particularly since the roots give off enough weak acid from their surface to corrode the surface of stones which they enfold or cover.

62. Osmosis. — The process by which two liquids separated by membranes pass through the latter and mingle, as soil-water does with the liquid contents of root-hairs, is called *osmosis*.

It is readily demonstrated by experiments with thin animal or vegetable membranes.

EXPERIMENT XV

Osmosis as shown in an Egg. — Cement to the smaller end of an egg a bit of glass tubing about six inches long and about three-sixteenths of an inch inside diameter. Sealing-wax or a mixture of equal parts of beeswax and resin melted together will serve for a cement.

Chip away part of the shell from the larger end of the egg, place it in a wide-mouthed bottle or a small beaker full of water, as shown in Fig. 24, then very cautiously pierce a hole through the upper end of the eggshell by pushing a knitting-needle or wire down through the glass tube.

Watch the apparatus for some hours and note any change in the contents of the tube.[1] Explain.

The rise of liquid in the tube is evidently due to water making its way through the thin membrane which lines the eggshell, although this membrane contains no pores visible even under the microscope.

EXPERIMENT XVI

Result of placing Sugar on a Begonia Leaf. — Place a little powdered sugar on the upper surface of a thick begonia leaf under a small bell-glass. Put another portion of sugar or a bit of paper alongside the leaf. Watch for several days. Explain results. The *upper* surface of this leaf contains no pores, even of microscopic size.

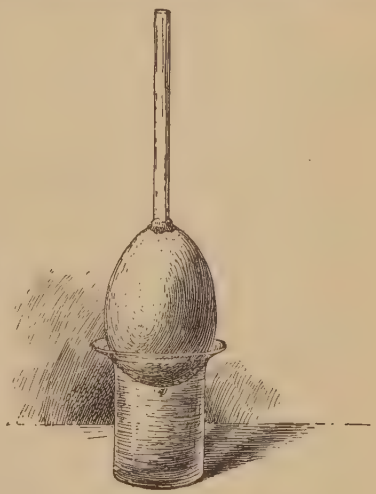


FIG. 24. — Egg on Beaker of Water, to show Osmosis.

63. Inequality of Osmotic Exchange. — The nature of the two liquids separated by any given membrane determines in which direction the greater flow shall take place.

If one of the liquids is pure water and the other

[1] Testing the contents of the beaker with nitrate of silver solution will then show the presence of more common salt than is found in ordinary water. Explain.

is water containing solid substances dissolved in it, the greater flow of liquid will be away from the pure water into the solution, and the stronger or denser the latter, the more unequal will be the flow. This principle is well illustrated by the egg-osmosis experiment. Another important principle is that substances which readily crystallize and are easily soluble, like salt or sugar, pass rapidly through membranes, while jelly-like substances, like white of egg, can hardly pass through them at all.

64. Study of Osmotic Action of Living Protoplasm; Plasmolysis. — The obvious parts of most living and growing plant-cells are a cell-wall, which is a skin or enclosure made of *cellulose*, and the living, active cell-contents or *protoplasm*. Every one is familiar with cellulose in various forms, one of the best examples being that afforded by clean cotton. It is a tough, white or colorless substance, chemically rather inactive. Protoplasm is a substance which differs greatly in its appearance and properties under different circumstances. It is of a very complex nature, so far as its chemical composition is concerned, belonging to the group of proteids and therefore containing not only the elements carbon, hydrogen, and oxygen, common to most organic substances, but nitrogen in addition. The protoplasm in a living cell often consists of several kinds of material; for instance, a rather opaque portion called the nucleus, and a more or less liquid portion lining the cell-walls and extending inward in strands to the nucleus (Fig. 126). Often, in living and active cells, the spaces left between strands and lining are filled with a watery liquid called the *cell-sap*.

The action of the protoplasm in controlling osmosis is well shown by the process known as *plasmolysis*.

Put some living threads of pond-scum (*Spirogyra*) (Chapter XX) into a 4 per cent solution of glycerine in water, a 16 per cent solution of cane sugar, or (for quick results) a 2 per cent solution of common salt.[1] Any one of these solutions is much denser than the cell-sap inside the cells of the pond-scum, and therefore the watery part of the cell-contents will be drawn out of the interior of the cell and the protoplasmic lining will collapse, receding from the cell-wall. The cell-contents are then said to be *plasmolyzed*. Sketch several cells in this condition. Remove the filaments of *Spirogyra* and place them in fresh water. How do they now behave? Explain. Repeat the plasmolyzing operation with another set of cells which have first been killed by soaking them for five minutes in a mixture of equal quantities of acetic acid, three parts to 1000 of water, and chromic acid, seven parts to 1000 of water. The pond-scum threads before being transferred from the killing solution into the plasmolyzing solution should be rinsed with a little clear water. Note how the cells now behave. How is it shown that they have lost their power of causing a liquid to be transferred mainly or wholly in one direction? Why do frozen or boiled slices of a red beet color water in which they are placed, while fresh slices do not?

65. Osmosis in Root-Hairs. — The soil-water (practically identical with ordinary spring or well water) is separated from the more or less sugary or mucilaginous sap inside of the root-hairs only by their delicate cell-walls, lined with a thin layer of protoplasm. This soil-water will pass rapidly into the plant, while very little of the sap will come out. The selective action, which causes the flow of liquid through the root-hairs to be almost wholly inward, is due to the living layer of protoplasm (Chapter XII), which covers the inner surface of the cell-wall of the root-hair. When the student has learned how active a substance protoplasm often shows itself to be, he will not be astonished to find it behaving almost as though it were

[1] This should be done as a demonstration by the teacher.

possessed of intelligence and will. Plants of two different species, both growing in the same soil, usually take from it very various amounts or kinds of mineral matter. For instance, barley plants in flower and red-clover plants in flower contain about the same proportion of mineral matter (left as ashes after burning). But the clover contains $5\frac{2}{3}$ times as much lime as the barley, and the latter contains about eighteen times as much silica as the clover. This difference must be due to the selective action of the protoplasm in the absorbing cells of the roots. Traveling by osmotic action from cell to cell, a current of water derived from the root-hairs is forced up through the roots and into the stem, just as the contents of the egg was forced up into the tube shown in Fig. 24.

66. **Sap-Pressure.** — The force with which the upward-flowing current of water presses may be estimated by attaching a mercury gauge to the root of a tree or the stem of a small sapling. This is best done in early spring after the thawing of the ground, but before the leaves have appeared. The experiment may also be performed indoors upon almost any plant with a moderately firm stem, through which the water from the soil rises freely. A dahlia plant or a tomato plant answers well, though the sap-pressure from one of these will not be nearly as great as that from a larger shrub or a tree growing out of doors. In Fig. 25 the apparatus is shown attached to the stem of a dahlia. The difference of level of the mercury in the bent tube serves to measure the sap-pressure. For every foot of difference in level there must be a pressure of nearly six pounds per square inch on the stump at the base of the tube *T*.[1]

[1] See *Handbook*.

A black-birch root tested in this way at the end of April has given a root-pressure of thirty-seven pounds to the square inch. This would sustain a column of water about eighty-six feet high.

67. Root-Absorption and Temperature of Soil. — It would not be remarkable if the temperature of roots and the earth about them had something to do with the rate at which they absorb water, since this absorption depends on the living protoplasm of the root-hairs (see Sects. 64, 65). An experiment will serve to throw some light on this question.

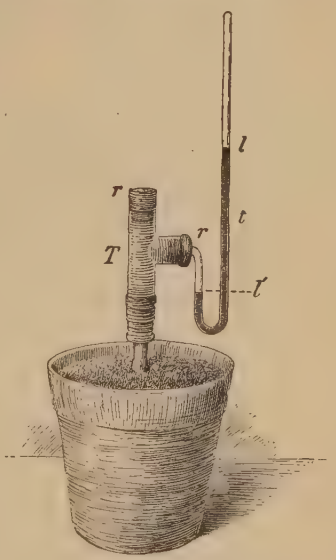


FIG. 25. — Apparatus to Measure Root-Pressure.

T, large tube fastened to the stump of the dahlia stem by a rubber tube; *r r*, rubber stoppers; *t*, bent tube containing mercury; *l l'*, upper and lower level of mercury in *T*.

EXPERIMENT XVII

Effect of Temperature on Absorption of Water by Roots. — Transplant a tobacco seedling about four inches high into rich earth contained in a narrow, tall beaker or very large test-tube (not less than $1\frac{1}{4}$ inch in diameter and six inches high). When the plant has begun to grow again freely, in a warm, sunny room, insert a chemical thermometer into the earth, best by making a hole with a sharp round stick, pushed nearly to the bottom of the tube, and then putting the thermometer in the place of the stick. Water the plant well, then set the tube in a jar of pounded ice which reaches nearly to the top of the tube. Note the temperature of the earth just before placing it in the ice. Observe whether the leaves of the seedling wilt,

and, if so, at what temperature the wilting begins. Finally, remove the tube from the ice and place it in warm water (about 80°). Observe the effect and note the temperature at which the plant, if wilted, begins to revive. Find an average between the wilting temperature and the reviving temperature. For what does this average stand?

68. Movements of Young Roots. — The fact that roots usually grow downward is so familiar that we do not generally think of it as a thing that needs discussion or explanation. Since they are pretty flexible, it may seem as though young and slender roots merely hung down by their own weight, like so many bits of wet cotton twine. But a very little experimenting will answer the question whether this is really the case.

EXPERIMENT XVIII

Do all Parts of the Root of the Windsor Bean Seedling bend downward alike? — Fasten some sprouting Windsor beans with roots about an inch in length to the edges of a disk of pine wood or other soft wood in a soup-plate nearly full of water and cover them with a low bell-jar. Pins run through the cotyledons, as in Fig. 26, will hold the beans in place. When the roots have begun to point downward strongly, turn most of the beans upside down and pin them in the reversed position. If you choose, after a few days reverse them again. Make sketches of the various forms that the roots assume and discuss these.

EXPERIMENT XIX

Does the Windsor Bean Root-Tip press downward with a Force greater than its Own Weight? — Arrange a sprouted bean as shown in Fig. 26, selecting one that has a root about twice as long as the diameter of the bean and that has grown out horizontally, having been sprouted on a sheet of wet blotting paper. The bean is pinned

to a cork that is fastened with beeswax and resin mixture to the side of a little trough or pan of glass or glazed earthenware. The pan is filled half an inch or more with mercury, and on top of the mercury is a layer of water. The whole is closely covered by a large tumbler or a bell-glass. Allow the apparatus to stand until the root has forced its way down into the mercury. Then run a slender needle into the root where it enters the mercury (to mark the exact level), withdraw the root, and measure the length of the part submerged in mercury. To see whether this part would have stayed under by virtue of its own weight, cut it off and lay it on the mercury. Push it under with a pair of steel forceps and then let go of it. What does it do?

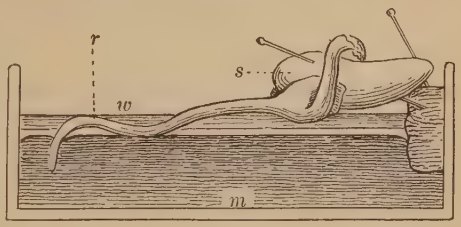


FIG. 26. — A Sprouting Windsor Bean pushing its Root-Tip into Mercury.

s, seed; *r*, root; *w*, layer of water; *m*, mercury.

69. Discussion of Exp. XIX. — By comparing the weights of equal bulks of mercury and Windsor bean roots, it is found that the mercury is about fourteen times as heavy as the substance of the roots. Evidently, then, the submerged part of the root must have been held under by a force about fourteen times its own weight. Making fine equidistant cross-marks with ink along the upper and the lower surface of a root that is about to bend downward at the tip, readily shows that those of the upper series soon come to be farther apart, — in other words, that *the root is forced to bend downward by the more rapid growth of its upper as compared with its under surface.*

70. Geotropism. — The property which plants or their organs manifest, of assuming a definite direction with

reference to gravity,[1] is called *geotropism*. When, as in the case of the primary root, the effect of gravity is to make the part if unobstructed turn or move downward, we say that the geotropism is *positive*. If the tendency is to produce upward movement, we say that the geotropism is *negative*; if horizontal movement, that it is *lateral*. It was stated in the preceding section that the direct cause of the downward extension of roots is unequal growth. We might easily suppose that this unequal growth is not due to gravity, but to some other cause. To test this supposition, the simplest plan (if it could be carried out) would be to remove the plants studied to some distant region where gravity does not exist. This of course cannot be done, but we can easily turn a young seedling over and over so that gravity will act on it now in one direction, now in another, and so leave no more impression than if it did not act at all (Exp. XX). Or we can whirl a plant so fast that not only is gravity done away with, but another force is introduced in its place. If a vertical wheel, like a carriage wheel, were provided with a few loosely fitting iron rings strung on the spokes, when the wheel was revolved rapidly the rings would all fly out to the rim of the wheel. So in Fig. 27 it will be

FIG. 27.—Sprouting Peas, on the Disk of a rapidly Whirling Clinostat.

The youngest portions of the roots all point directly away from the axis about which they were revolved.

[1] Gravity means the pull which the earth exerts upon all objects on or near its surface.

noticed that the growing tips of the roots of the sprouting peas point almost directly outward from the center of the disk on which the seedlings are fastened. Explain the difference between this result and that obtained in Exp. XX.

EXPERIMENT XX

How do Primary Roots point when uninfluenced by Gravity? Pin some soaked Windsor beans to a large flat cork, cover them with thoroughly moistened chopped peat-moss, and cover this with a thin glass crystallizing dish. Set the cork on edge. Prepare another cork in the same way, attach it to a clinostat, and keep it slowly revolving in a vertical position for from three to five days. Compare the directions taken by the roots on the stationary and on the revolving cork.[1]

71. Direction taken by Secondary Roots. — As the student has already noticed in the seedlings which he has studied, the branches of the primary root usually make a considerable angle with it (Fig. 2). Often they run out for long distances almost horizontally. This is especially common in the roots of forest trees, above all in cone-bearing trees, such as pines and hemlocks. This horizontal or nearly horizontal position of large secondary roots is the most advantageous arrangement to make them useful in staying or guying the stem above, to prevent it from being blown over by the wind.

72. Fitness of the Root for its Position and Work. — The distribution of material in the woody roots of trees and shrubs and their behavior in the soil show many adaptations to the conditions by which the roots are surrounded.

[1] See Ganong's *Teaching Botanist*, pp. 182–186, for complete directions. The brief statement above given is abstracted from that of Professor Ganong.

The growing tip of the root, as it pushes its way through the soil, is exposed to bruises; but these are largely warded off by the root-cap. The tip also shows a remarkable sensitiveness to contact with hard objects, so that when touched by one it swerves aside and thus finds its way downward by the easiest path. Roots with an unequal water supply on either side grow toward the moister soil. Roots are very tough, because they need to resist strong

FIG. 28. — Roots of a Western Hemlock exposed by having most of the Leaf-Mould about them burned away by Forest Fires.

pulls, but not as stiff as stems and branches of the same size, because they do not need to withstand sidewise pressure, acting from one side only. The corky layer which covers the outsides of roots is remarkable for its power of preventing evaporation. It must be of use in retaining in the root the moisture which otherwise might be lost on its way from the deeper rootlets (which are buried in damp soil), through the upper portions of the root-system, about which the soil is often very dry.

73. Propagation by Means of Roots. — Some familiar plants, such as rose bushes, are usually grown from roots or root-cuttings.

Bury a sweet potato or a dahlia root in damp sand, and watch the development of sprouts from adventitious buds. One sweet potato will produce several such crops of sprouts, and every sprout may be made to grow into a new plant. It is in this way that the crop is started wherever the sweet potato is grown for the market.

74. Tabular Review of Experiments.

[Continue the table begun at end of Chapter III.]

75. Review Summary of Roots.

Kinds of roots as regards origin . . . . . {

Kinds as regards medium in which they grow . {

Structure of root of a tree.

Storage in roots . . . . . { materials. location. uses.

Absorption of water by roots . . . . . { apparatus. amount. proofs. causes.

Movements of roots . . . . . { nature. causes. uses.

CHAPTER V

STEMS

76. What the Stem is. — The work of taking in the raw materials which the plant makes into its own food is done mainly by the roots and the leaves. These raw materials are taken from earth, from water, and from the air (see Chapter XI). The stem is that part or organ of the plant which serves to bring roots and leaves into communication with each other. In most flowering plants the stem also serves the important purpose of lifting the leaves up into the sunlight, where alone they best can do their special work.

The student has already, in Chapter III, learned something of the development of the stem and the seedling; he has now to study the external appearance and internal structure of the mature stem. Much in regard to this structure can conveniently be learned from the examination of twigs and branches of our common forest trees in their winter condition.

77. The Horse-Chestnut Twig.[1] — Procure a twig of horse-chestnut eighteen inches or more in length. Make a careful sketch of it, trying to bring out the following points:

(1) The general character of the bark.

[1] Where the buckeye is more readily obtained it will do very well. Hickory twigs answer the same purpose, and the latter is a more typical form, having alternate buds. The magnolia or the tulip tree will do. The student should (sooner or later) examine at least one opposite- and one alternate-leaved twig.

(2) The large horseshoe-shaped scars and the number and position of the dots on these scars. Compare a scar with the base of a leaf-stalk furnished by the teacher.

(3) The ring of narrow scars around the stem in one or more places,[1] and the different appearance of the bark above and below such a ring. Compare these scars with those left after removing the scales of a terminal bud and then see Fig. 29, *b sc*.

(4) The buds at the upper margin of each leaf-scar and the strong terminal bud at the end of the twig.

(5) The flower-bud scar, a concave impression, to be found in the angle produced by the forking of two twigs, which form, with the branch from which they spring, a Y-shaped figure (see Fig. 36).

(6) (On a branch larger than the twig handed round for individual study) the place of origin of the twigs on the branch; — make a separate sketch of this.

The portion of stem which originally bore any pair of leaves is called a *node*, and the portions of stem between nodes are called *internodes*.

Describe briefly in writing alongside the sketches any observed facts which the drawings do not show.

If your twig was a crooked, rough-barked, and slow-growing one, exchange it for a smooth, vigorous one, and note the differences. Or if you sketched a quickly grown shoot, exchange for one of the other kind.

FIG. 29. — A quickly grown Twig of Cherry, with Lateral and Terminal Buds in October.

b sc, bud-scale scars. All above these scars is the growth of the spring and summer of the same year.

Answer the following questions :

(*a*) How many inches did your twig grow during the last summer?

How many in the summer before?

How do you know?

How many years old is the whole twig given you?

(*b*) How were the leaves arranged on the twig?

[1] A very vigorous shoot may not show any such ring.

How many leaves were there?

Were they all of the same size?

(*c*) What has the mode of branching to do with the arrangement of the leaves? with the flower-bud scars?

(*d*) The dots on the leaf-scars mark the position of the bundles of ducts and wood-cells which run from the wood of the branch through the leaf-stalk up into the leaf.

78. Twig of Poplar. — Sketch a vigorous young twig of poplar (or of hickory, magnolia, tulip tree) in its winter condition, noting particularly the respects in which it differs from the horse-chestnut. Describe in writing any facts not shown in the sketch. Notice that the buds are not opposite, nor is the next one above any given bud found directly above it, but part way round the stem from the position of the first one. Ascertain, by studying several twigs and counting around, which bud is above the first and how many turns round the stem are made in passing from the first to the one directly above it.

Observe with especial care the difference between the poplar and the horse-chestnut in mode of branching, as shown in a large branch provided for the study of this feature.

79. Relation of Leaf-Arrangement to Branching.[1] — This difference, referred to in Sect. 78, depends on the fact that the leaves of the horse-chestnut were arranged in pairs, on opposite sides of the stem, while those of the poplar were not in pairs. Since the buds are found at the upper edges of the leaf-scars, and since most of the buds of the horse-chestnut and the poplar are leaf-buds and destined to form branches, the mode of branching and ultimately the form

[1] The teacher in the Eastern and Middle States will do well to make constant use, in the study of branches and buds, of Miss Newell's *Outlines of Lessons in Botany*, Part I. The student can observe for himself, with a little guidance from the teacher, most of the points which Miss Newell suggests. If the supply of material is abundant, the twigs employed in the lessons above described need not be used further, but if material is scanty, the study of buds may at once be taken up. (See also Bailey's *Lessons with Plants*, Part I.)

of the tree must depend largely on the arrangement of leaves along the stem.

80. Opposite Branching. — In trees the leaves and buds of which are opposite, the tendency will be to form twigs in four rows about at right angles to each other along the sides of the branch, as shown in Fig. 30.

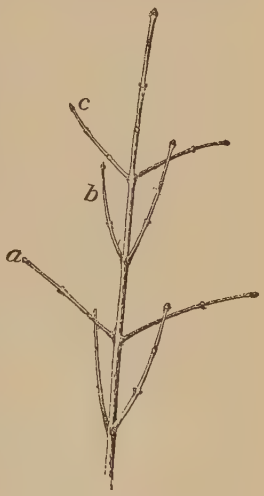


FIG. 30. — Opposite Branching in a very Young Sapling of Ash.

This arrangement will not usually be perfectly carried out, since some of the buds may never grow, or some may grow much faster than others and so make the plan of branching less evident than it would be if all grew alike.

FIG. 31. — Alternate Branching in a very Young Apple Tree.

81. Alternate Branching. — In trees like the poplar the twigs will be found to be arranged in a more or less regular spiral line about the branch. This, which is known as the *alternate* arrangement (Fig. 31), is more commonly met with in trees and shrubs than the *opposite* arrangement. It admits of many varieties, since the spiral may wind more or less rapidly round the stem. In the apple, pear, cherry, poplar, oak, and walnut, one passes

FIG. 32. — Excurrent Trunks of Big Trees (*Sequoias*).

over five spaces before coming to a leaf which is over the first, and in doing this it is necessary to make two complete turns round the stem (Fig. 105).

82. Growth of the Terminal Bud. — In some trees the terminal bud from the very outset keeps the leading place, and the result of this mode of growth is to produce a slender, upright tree, with an *excurrent* trunk like that of Fig. 32.

In such trees as the apple and many oaks the terminal bud has no preeminence over others, and the form of the tree is round-topped and spreading, *deliquescent* like that in Fig. 33.

Most of the larger forest trees are intermediate between these extremes.

Branches get their characteristics to a

FIG. 33.—An American Elm, with Deliquescent Trunk.

considerable degree from the relative importance of their terminal buds. If these are mainly flower-buds, as is the case in the horse-chestnut and some magnolias (Figs. 35, 36),

the tree is characterized by frequent forking, and has no long horizontal branches.

If the terminal bud keeps the lead of the lateral ones, but the latter are numerous and most of them grow into slender twigs, the delicate spray of the elm and many birches is produced (Fig. 37).

The general effect of the branching depends much upon the angle which each branch or twig forms with that one from which it springs. The angle may be quite acute, as in the birch; or more nearly a right angle, as in the ash (Fig. 30). The inclination of lateral branches is due to geotropism, just as is that of the branches of primary roots. The vertically upward direction of the shoot which grows from the terminal bud is also due to geotropism.

This is really only a brief way of saying that the growing tip of the main stem of the tree or of any branch is made to take and keep its proper direction, whether vertically upward or at whatever angle is desirable for the tree, by the steering action of gravity. After growth has ceased this steering action can no longer be exerted, and so a tree that has been bent over (as, for instance, by a heavy load of snow) cannot right itself, unless it is elastic enough to spring back when the load is removed. The tip of the trunk and of each branch can grow and thus become vertical, but the old wood cannot do so.

83. Thorns as Branches. — In many trees some branches show a tendency to remain dwarfish and incompletely developed. Such imperfect branches forming thorns are familiar in wild crab-apple trees and in the pear trees which occur in old pastures in the Northeastern States. In the honey locust very formidable branching spines spring

from adventitious or dormant buds on the trunk or limbs. Such spines sometimes show their true nature as branches by bearing leaves (Fig. 34).

84. Indefinite Annual Growth. — In most of the forest trees, and in the larger shrubs, the wood of young branches is matured and fully developed during the summer. Protected buds are formed on the twigs of these branches to their very tips. In other shrubs — for example, in the sumac, the raspberry, and blackberry — the shoots continue to grow until their soft and immature tips are killed by the frost. Such a mode of growth is called *indefinite annual growth*, to distinguish it from the *definite annual growth* of most trees.

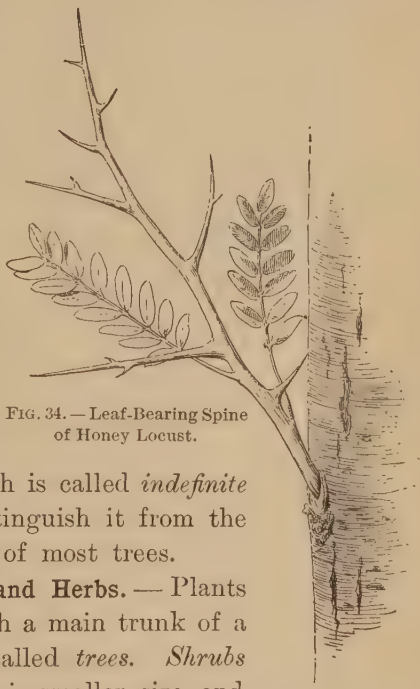


FIG. 34. — Leaf-Bearing Spine of Honey Locust.

85. Trees, Shrubs, and Herbs. — Plants of the largest size with a main trunk of a woody structure are called *trees*. *Shrubs* differ from trees in their smaller size, and generally in having several stems which proceed from the ground or near it or in having much-forked stems. The witch-hazel, the dogwoods, and the alders, for instance, are most of them classed as shrubs for this reason, though in height some of them equal the smaller trees. Some of

the smallest shrubby plants, like the dwarf blueberry, the wintergreen, and the trailing arbutus, are only a few inches

FIG. 35. — Tip of a Branch of Magnolia, illustrating Forking due to Terminal Flower-Buds.

A, oldest flower-bud scar; *B*, *C*, *D*, scars of successive seasons after *A*; *L*, leaf-buds; *F*, flower-buds.

in height, but are ranked as shrubs because their woody stems do not die quite to the ground in winter.

Herbs are plants whose stems above ground die every winter.

86. Annual, Biennial, and Perennial Plants. — *Annual* plants are those which live but one year, *biennials* those which live two years or nearly so.

Some annual plants may be made to live over winter, flowering in their second summer. This is true of winter wheat and rye among cultivated plants.

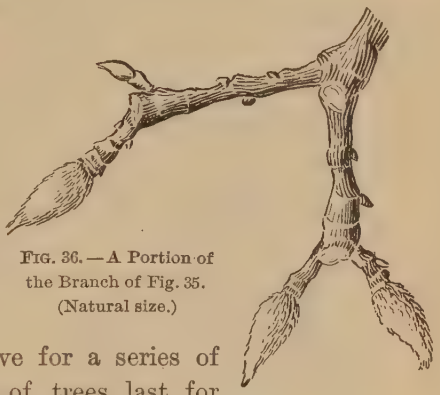


FIG. 36. — A Portion of the Branch of Fig. 35. (Natural size.)

Perennial plants live for a series of years. Many kinds of trees last for centuries. The Californian giant redwoods, or *Sequoias* (Fig. 32), which reach a height of over 300 feet under favorable circumstances, live nearly 2000 years; and some

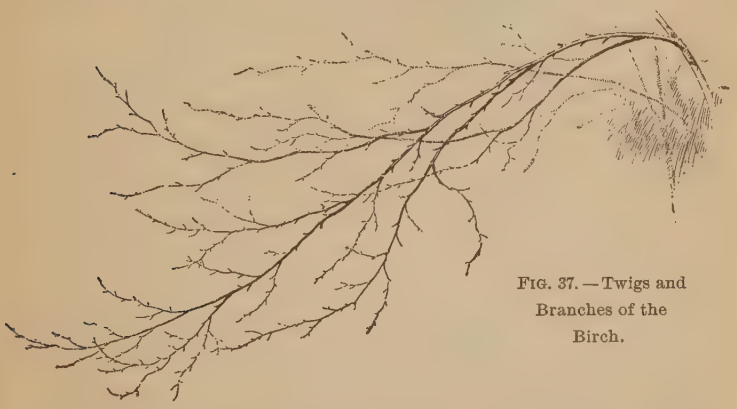


FIG. 37. — Twigs and Branches of the Birch.

monstrous cypress trees found in Mexico were thought by Professor Asa Gray to be from 4000 to 5000 years old.

87. Stemless Plants. — As will be shown later (Chapter XXX), plants live subject to a very fierce competition among themselves and exposed to almost constant attacks from animals.

While plants with long stems find it to their advantage to reach up as far as possible into the sunlight, the cinquefoil, the white clover, the dandelion, some spurges, the knotgrass, and hundreds of other kinds of plants have found safety in hugging the ground.

FIG. 38. — The Dandelion ; a so-called Stemless Plant.

Any plant which can grow in safety under the very feet of grazing animals will be especially likely to make its way in the world, since there are many places where it can flourish while ordinary plants would be destroyed. The bitter, stemless dandelion, which is almost uneatable for most animals, unless cooked, which lies too near the earth to be fed upon by grazing animals, and which bears being trodden on with impunity, is a type of a large class of hardy weeds.

The so-called *stemless plants*, like the dandelion (Fig. 38), and some violets, are not really stemless at all, but send

out their leaves and flowers from a very short stem, which hardly rises above the surface of the ground.

88. Climbing and Twining Stems.[1] — Since it is essential to the health and rapid growth of most plants that they should have free access to the sun and air, it is not strange that many should resort to special devices for lifting themselves above their neighbors. In tropical forests, where the darkness of the shade anywhere beneath the tree-tops is so great that few flowering plants can thrive in it, the climbing plants or *lianas* often run like great cables for hundreds of feet before they can emerge into the sunshine above. In temperate climates no such remarkable climbers are found, but many plants raise themselves for considerable distances. The principal means to which they resort for this purpose are :

FIG. 39. — Lianas strangling a Palm.

(1) Producing roots at many points along the stem above ground and climbing on suitable objects by means of these, as in the English ivy (Fig. 15).

(2) Laying hold of objects by means of tendrils or *twining branches* or *leaf-stalks*, as shown in Figs. 40, 41.

[1] See Kerner and Oliver's *Natural History of Plants*, Vol. I, p. 669.

(3) Twining about any slender upright support, as shown in Fig. 42.

89. Tendril-Climbers. — The plants which climb by means of tendrils are important subjects for study, but they cannot usually be managed very well in the schoolroom. Continued observation soon shows that the tips of tendrils sweep slowly about in the air until they come in contact with some object about which they can coil themselves. After the tendril has taken a few turns about its support, the free part of the tendril coils into a spiral and thus draws the whole stem toward the point of attachment, as shown in Fig. 40. Some tendrils are modified leaves or stipules, as shown in Fig. 104; others are modified stems.

Fig 40. — Coiling of a Tendril of Bryony.

90. Twiners. — Only a few of the upper internodes of the stem of a twiner are concerned in producing the movements of the tip of the stem. This is kept revolving in an elliptical or circular path until it encounters some roughish and not too stout object, about which it then proceeds to coil itself.

The movements of the younger internodes of the stems of twiners are among the most extensive of all the movements made by plants. A hop-vine which has climbed to the top of its stake may sweep its tip continually around the circumference of a circle two feet in diameter, and the

common wax-plant of the greenhouses sometimes describes a five-foot circle, the tip moving at the rate of thirty-two inches per hour.[1] This circular motion results from some cause not yet fully understood by botanists.[2]

The direction in which twiners coil about a supporting object is almost always the same for each species of plant, but not the same for all species. In the hop it is as shown in Fig. 42. Is it the same as in the bean? in the morning-glory?

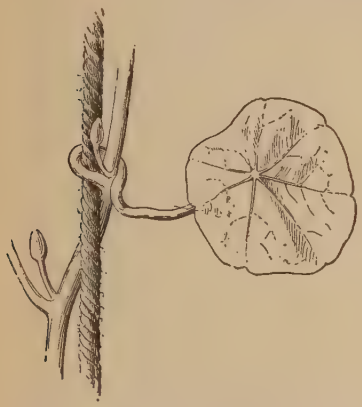


FIG. 41. — Coiling of Petiole of Dwarf Tropæolum.

FIG. 42. — Twining Stem of Hop.

91. Underground Stems. — Stems which lie mainly or wholly underground are of frequent occurrence and of many kinds.

In the simplest form of *rootstock* (Fig. 43), such as is

[1] See article on *Climbing Plants*, by Dr. W. J. Beal, in the *American Naturalist*, Vol. IV, pp. 405–415.

[2] See Strasburger, Noll, Schenk, and Karsten's *Text-Book*, pp. 281–284; also Vines' *Students' Text-Book of Botany*, London and New York, 1894, pp. 759, 760.

found in some mints and in many grasses and sedges, the real nature of the creeping underground stem is shown by the presence upon its surface of many scales, which are reduced leaves. Rootstocks of this sort often extend horizontally for long distances in the case of grasses like the sea rye grass (Plate I), which roots itself firmly and thrives in shifting sand-dunes. In the stouter rootstocks, like that of the iris (Fig. 44) and the Caladium (Fig. 45), this stem-like character is less evident. The potato is an excellent example of the short and much-thickened underground stem known as a *tuber*.

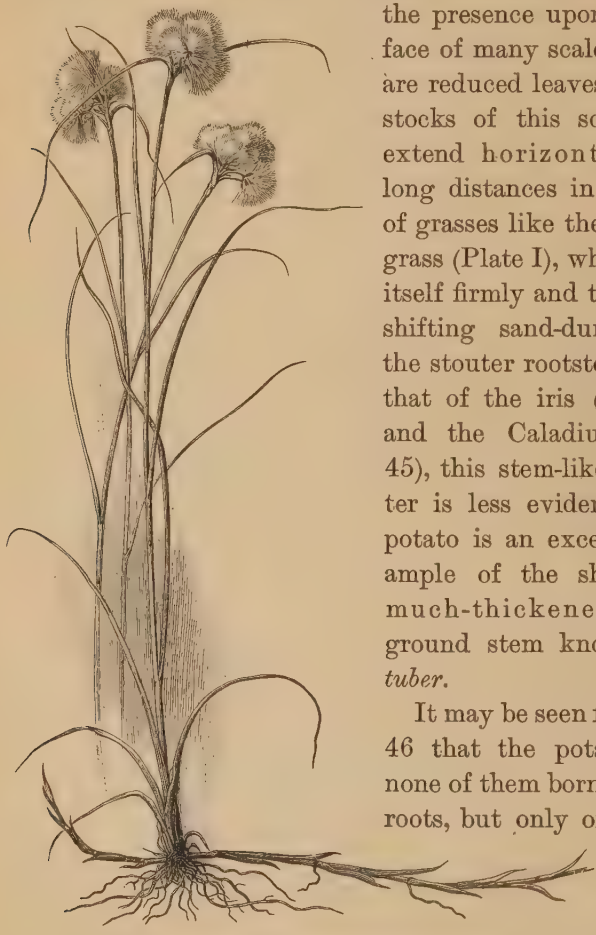


FIG. 43.—Rootstock of Cotton-Grass (*Eriophorum*).

It may be seen from Fig. 46 that the potatoes are none of them borne on true roots, but only on subterranean branches, which are stouter and more cylindrical than most of the roots. The "eyes"

PLATE I. — A Sand-Loving Plant, Sea Rye Grass

FIG. 44. — Roots, Rootstocks, and Leaves of Iris.

which they bear are rudimentary leaves and buds.

Bulbs, whether coated like those of the onion or the hyacinth (Fig. 47), or scaly like those of the lily, are merely very short and stout underground stems, covered with closely crowded scales or layers which represent leaves or the bases of leaves (Fig. 48).

The variously modified forms of underground stems just discussed, illustrate in a marked way the storage of nourishment during the winter (or the rainless season, as the case may be) to secure rapid growth during the active season. It is interesting to notice that nearly all of the early-flowering herbs in temperate climates, like the crocus, the snowdrop, the spring-beauty, the

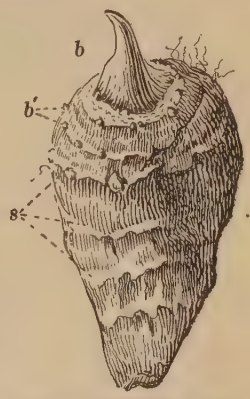


FIG. 45. — Rootstock of Caladium (*Colocasia*).

b, terminal bud; *b'*, buds arranged in circles where bases of leaves were attached; *s*, scars left by sheathing bases of leaves.

tulip, and the skunk-cabbage, owe their early-blooming habit to richly stored underground stems of some kind, or to thick, fleshy roots.

92. Condensed Stems. — The plants of desert regions require, above all, protection from the extreme dryness of the surrounding air, and, usually, from the excessive heat of the sun. Accordingly, many desert plants are found quite destitute of ordinary foliage, exposing to the air only a small surface. In the melon-cactuses (Fig. 49) the stem appears reduced to the shape in which the least possible surface is presented by a plant of given bulk, — that is, in a globular form. Other cactuses are more or less cylindrical or prismatic, while still others consist of flattened joints; but all agree in offering much less area to the sun and air than is exposed by an ordinary leafy plant.

FIG. 46. — Part of a Potato Plant.
The dark tuber in the middle is the one from which the plant has grown.

93. Leaf-Like Stems. — The flattened stems of some kinds of cactus (especially the common, showy *Phyllocactus*) are sufficiently like fleshy leaves, with their dark green color and imitation of a midrib, to pass for leaves. There are,

however, a good many cases in which the stem takes on a more strikingly leaf-like form. The common asparagus sends up in spring shoots that bear large scales which are really reduced leaves. Later in the season, what seem like thread-like leaves cover the much-branched mature plant, but these green threads are actually minute branches, which perform the work of leaves (Fig. 50). The familiar greenhouse climber, wrongly known as smilax (properly called *Myrsiphyllum*), bears a profusion of what appear to be delicate green leaves (Fig. 51). Close study, however, shows that these are really short, flattened branches, and that each little branch springs from the axil of a true leaf, *l*, in the form of a minute scale. Sometimes a flower and a leaf-like branch spring from the axil of the same scale.

FIG. 47. — Bulb of Hyacinth. (Exterior view and split lengthwise.)

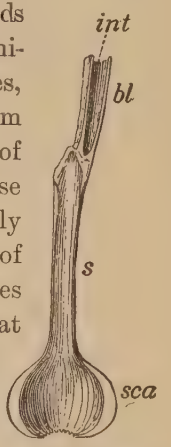


FIG. 48. — Longitudinal Section of an Onion Leaf.

sca, thickened base of leaf, forming a bulb-scale; *s*, thin sheath of leaf; *bl*, blade of the leaf; *int*, hollow interior of blade.

Branches which, like those of *Myrsiphyllum*, so closely resemble leaves as to be almost indistinguishable from them are called *cladophylls*.

94. Modifiability of the Stem. — The stem may, as in the tallest trees, in the great lianas of South American forests,

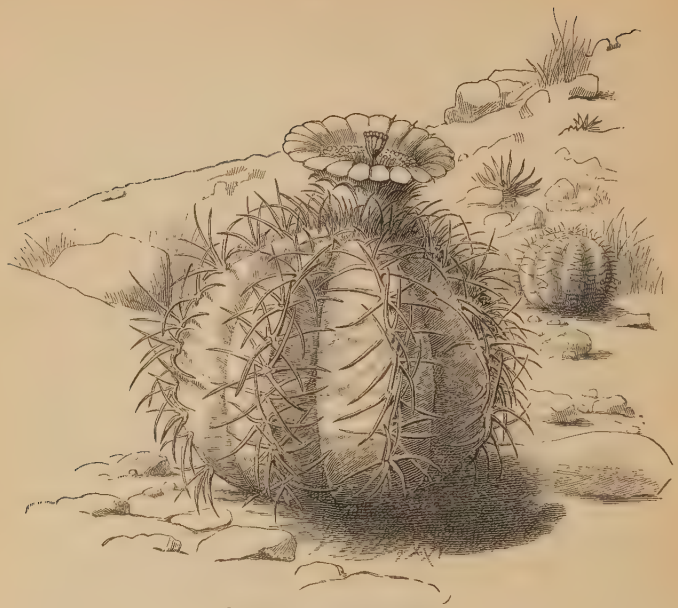


FIG. 49. — A Melon-Cactus.

FIG. 50. — A Spray of a Common Asparagus (not the edible species).

or the rattan of Indian jungles, reach a length of many hundred feet. On the other hand, in such "stemless" plants as the primrose and the dandelion, the stem may be reduced to a fraction of an inch in length. It may take

FIG. 51.—Stem of "Smilax" (*Myrsiphyllum*).
l, scale-like leaves; *cl*, cladophyll, or leaf-like branch, growing in the axil of the leaf; *ped*, flower-stalk, growing in the axil of a leaf.

on apparently root-like forms, as in many grasses and sedges, or become thickened by underground deposits of starch and other plant-food, as in the iris, the potato, and the crocus. Condensed forms of stem may exist above ground, or, on the other hand, branches may be flat and

thin enough closely to imitate leaves. In short, the stem manifests great readiness in adapting itself to the most varied conditions of existence.

95. Review Summary of Stems.[1]

Kinds of branching due to leaf arrangement . . . . { 1. 2.

Kinds of tree-trunk due to greater or less predominance of terminal bud . . . . . { 1 2.

Classes of plants based on amount of woody stem . . { 1. 2. 3.

Classes of plants based on duration of life . . . . . { 1. 2. 3.

Various modes of climbing . . . . . { 1. 2. 3.

Kinds of underground stem . . . . . { 1. 2. 3.

Condensed stems above ground . . . . . {

Leaf-like stems . . . . . {

[1] Where it is possible to do so, make sketches; where this is not possible, give examples of plants to illustrate the various kinds or classes of plants in the summary.

CHAPTER VI

STRUCTURE OF THE STEM

STEM OF MONOCOTYLEDONOUS PLANTS

96. Gross Structure. — Refer back to the sketches of the corn-seedling, to recall something of the early history of the corn-stem. Study the external appearance of a piece of corn-stem or bamboo two feet or more in length. Note the character of the outer surface. Sketch the whole piece and label the enlarged *nodes* and the nearly cylindrical *internodes*. Cut across a corn-stem and examine the cut surface with the magnifying glass. Make some sections as thin as they can be cut and examine with the magnifying glass (holding them up to the light) or with a dissecting microscope. Note the firm rind, composed of the epidermis and underlying tissue, the large mass of pith composing the main bulk of the stem, and the many little harder and more opaque spots, which are the cut-off ends of the woody threads known as *fibro-vascular bundles* (Fig. 52).

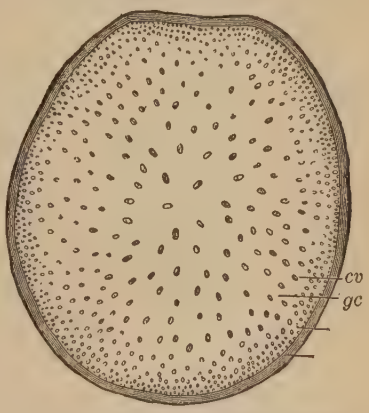


FIG. 52. — Diagrammatic Cross-Section of Stem of Indian Corn.

cv, fibro-vascular bundles; *gc*, pithy material between bundles.

Split a portion of the stem lengthwise into thin translucent slices and notice whether the bundles seem to run straight up and down its length; sketch the entire section × 2. Every fibro-vascular bundle of the stem passes outward through some node in order to connect with some fibro-vascular

bundle of a leaf. This fact being known to the student would lead him to expect to find the bundles bending out of a vertical position more at the nodes than elsewhere. Can this be seen in the stem examined?

Observe the enlargement and thickening at the nodes, and split one of these lengthwise to show the tissue within it.

Compare with the corn-stem a piece of palmetto and a piece of cat-brier (*Smilax rotundifolia*, *S. hispida*, etc.), and notice the similarity of structure, except for the fact that the tissue in the palmetto and the cat-brier which answers to the pith of the corn-stem is much darker colored and harder than corn-stem pith. Compare also a piece of rattan and of bamboo.

97. Minute Structure. — Cut a thin cross-section of the corn-stem, examine with a low power of the microscope, and note:

(*a*) The rind (not true bark), composed largely of hard, thick-walled dead cells, known as *sclerenchyma* fibers.

(*b*) The fibro-vascular bundles. Where are they most abundant? least abundant?

(*c*) The pith, occupying the intervals between the fibro-vascular bundles.

Study the bundles in various portions of the section and notice particularly whether some are more porous than others. Explain. Sketch some of the outer and some of the inner ones.

A more complicated kind of monocotyledonous stem-structure can be studied to advantage in the surgeons' splints cut from yucca-stems and sold by dealers in surgical supplies.

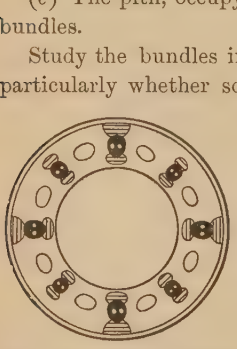


FIG. 53. — Diagrammatic Cross-Section of Stem of Bulrush (*Scirpus*), a Hollow Cylinder with Strengthening Fibers.

98. Mechanical Function of the Manner of Distribution of Material in Monocotyledonous Stems. — The well-known strength and lightness of the straw of our smaller grains and of rods of cane or bamboo are due to their form. It can readily be shown

by experiment that an iron or steel tube of moderate thickness, like a piece of gas-pipe, or of bicycle-tubing, is much stiffer than a solid rod of the same weight per foot. The oat straw, the stems of bulrushes (Fig. 53), the cane (of our southern canebrakes), and the bamboo are hollow cylinders; the cornstalk is a solid cylinder, but filled with a very light pith. The flinty outer layer of the stalk, together with the closely packed sclerenchyma fibers of the outer rind and the frequent fibro-vascular bundles just within this, are arranged in the best way to secure stiffness. In a general way, then, we may say that the pith, the bundles, and the sclerenchymatous rind are what they are and where they are to serve important mechanical purposes. But they have other uses fully as important (Fig. 78).

FIG. 54. — Group of Date-Palms.

99. Growth of Monocotyledonous Stems in Thickness. — In most woody monocotyledonous stems, for a reason

which will be explained later in this chapter, the increase in thickness is strictly limited. Such stems, therefore, as in many palms (Fig. 54) and in rattans, are less conical and more cylindrical than the trunks of ordinary trees and are also more slender in proportion to their height.

STEM OF DICOTYLEDONOUS PLANTS

100. Gross Structure of an Annual Dicotyledonous Stem. — Study the external appearance of a piece of sunflower-stem several inches long. If it shows distinct nodes, sketch it. Examine the cross-section and sketch it as seen with the magnifying glass or the dissecting microscope. *After your sketch is finished*, compare it with Fig. 55, which probably shows more details than your drawing, and label the parts shown as they are labeled in that figure. Split a short piece of the stem lengthwise through the center and study the split surface with the magnifying glass. Take a sharp knife or a scalpel and carefully slice and then scrape away the bark until you come to the outer surface of a bundle.

Examine a vegetable sponge (*Luffa*), sold by druggists, and notice that it is simply a network of fibro-vascular bundles. It is the skeleton of a tropical seed-vessel or fruit, very much like that of the wild cucumber, common in the Central States, but a great deal larger.

The different layers of the bark cannot all be well recognized in the examination of a single kind of stem. Examine (*a*) the *cork* which constitutes the outer layers of the bark of cherry or birch branches two or more years old. Sketch the roundish or oval spongy *lenticels* on the outer surface of the bark. How far in do they extend? Examine (*b*) the *green layer* of bark as shown in twigs or branches of Forsythia, cherry, alder, box-elder, wahoo, or willow. Examine (*c*) the white, fibrous inner layer, known as *hard bast*, of the bark of elm, leatherwood, pawpaw, or basswood.

101. Minute Structure of the Dicotyledonous Stem. — Study, first with a low and then with a medium power of the compound microscope, thin cross-sections of clematis-stem cut just before the end of

the first season's growth.[1] Sketch the whole section without much detail, and then make a detailed drawing of a sector running from center to circumference and just wide enough to include one of the large bundles. Label these drawings in general like Figs. 55, 56.

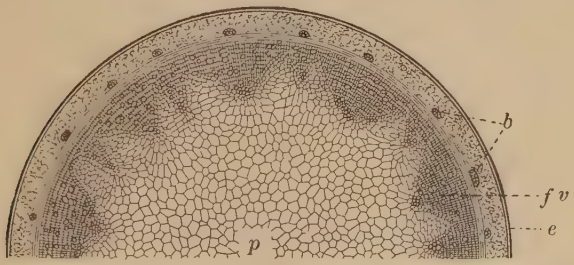


FIG. 55. — Diagrammatic Cross-Section of an Annual Dicotyledonous Stem. (Somewhat magnified.)

p, pith; *fv*, woody or fibro-vascular bundles; *e*, epidermis; *l*, bundles of hard bast fibers of the bark.

FIG. 56. — Diagrammatic Cross-Section of One-Year-Old *Aristolochia* Stem. (Considerably magnified.)

e, region of epidermis; *b*, hard bast; *o*, outer or bark part of a bundle (the cellular portion under the letter); *w*, inner or woody part of bundle; *c*, cambium layer; *p*, region of pith; *m*, a medullary ray.
The space between the hard bast and the bundles is occupied by thin-walled, somewhat cubical cells of the bark.

[1] *Clematis virginiana* is simpler in structure than some of the other woody species. *Aristolochia* sections will do very well.

Note:

(*a*) The general outline of the section.

(*b*) The number and arrangement of the bundles. (How many kinds of bundles are there?)

(*c*) The comparative areas occupied by the woody part of the bundle and by the part which belongs to the bark.

(*d*) The way in which the pith and the outer bark are connected (and the bundles separated) by the *medullary rays*.

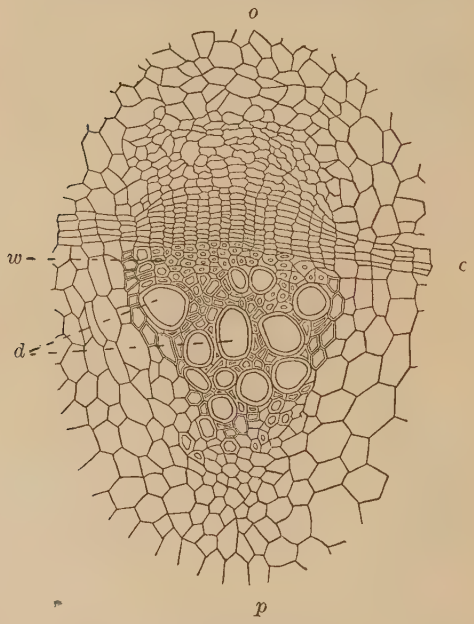


FIG. 57. — One Bundle from the Preceding Figure. (× 100.)

w, wood-cells; *d*, ducts. The other letters are as in Fig. 56. Many sieve-cells occur in the region just outside of the cambium of the bundle.

Examine a longitudinal section of the same kind of stem, to find out more accurately of what kinds of cells the pith, the bundles, and the outer bark are built. Which portion has cells that are nearly equal in shape, as seen in both sections?

102. Mechanical Importance of Distribution of Material in the Dicotyledonous Stem. — It is easy to see that those tissues which are tough, like hard bast, and those which are both tough and stiff, like wood fibers, are arranged in a tubular fashion in young dicotyledonous stems as they are in some monocotyledonous ones (Fig. 53). Sometimes the interior of the stem is quite hollow, as, for example,

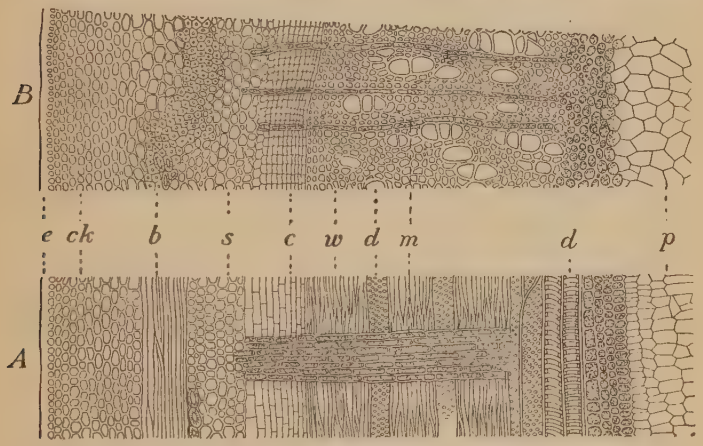


FIG. 58. — Stem of Box-Elder One Year Old. (Much magnified.)

A, lengthwise (radial) section ; *B*, cross-section ; *e*, epidermis ; *ck*, cork ; *b*, hard bast ; *s*, sieve-cells ; *c*, cambium ; *w*, wood-cells ; *m*, medullary rays ; *d*, ducts ; *p*, pith.

in the stems of balsams, melons, cucumbers, and squashes, and in the flower-stalks of the dandelion. In older stems, such as the trunks of trees, the wood forms a pretty nearly solid cylinder.

Stiffness in dicotyledonous stems is secured mainly in two ways : (1) by hard bast fibers, (2) by wood fibers. Which of these types does the stem (Fig. 55) represent? Which does the flax-stem (Fig. 60) represent?

Notice that in both types bast fibers and wood fibers are present, but the proportions in (1) and (2) vary greatly.

103. Kinds of Cells which compose Stems. — The student has already seen something of cells in the seed, in the roots of seedlings and mature plants, and in several kinds of stems. But he will need to become acquainted with a much larger variety of cells in the stem. The following materials will serve to illustrate some of the most important forms.[1]

Examine with a half-inch objective and one-inch eyepiece (or higher power) these preparations (1–9 below):

Study very carefully each of the sections described, find in it the kind of cell referred to in the corresponding number (1–9) of the following section (104), and make a good sketch of a group of cells of each kind as actually seen under the microscope.[2]

(1) Very thin sections of the epidermis of a potato, some cut parallel to the surface (*tangential*), others cut at right angles to the epidermis.

(2) Thin sections of the green layer of the bark of Forsythia, spindle tree (*Euonymus*), or box-elder (*Negundo*).

(3) Thin cross-sections and longitudinal sections of the inner bark of linden twigs, or of full-grown stems of flax.

(4) Longitudinal sections of the stem of squash or cucumber plants.

(5) Thin cross-sections of young twigs of pine or oak, cut in late summer.

(6) Thin cross-sections and longitudinal sections, cut from pith toward bark (*radial*) of young wood of sycamore, of sassafras, or of box-elder.

(7) Thin longitudinal sections of the stem of castor-oil plant (*Ricinus*) or of the stalk (peduncle) on which the fruit of the banana is supported.

[1] These studies may be made from sections cut by the pupil, by the teacher, or by a professional hand, as circumstances may dictate. The soft bast (No. 4, see p. 91) can best be studied in good prepared sections obtained of the dealers.

[2] Nothing can do so much to make these studies valuable as for the teacher to correct in class the errors of most frequent occurrence in the drawings, by aid of his own *camera lucida* drawings of the same objects.

(8) Thin longitudinal radial sections of sycamore, of sassafras, maple, or box-elder wood.

(9) Thin sections of elder pith, sunflower-stem pith, or of so-called Japanese "rice-paper."

104. Names of the Cells of Bark, Wood, and Pith. — No two varieties of stems will be found to consist of just the same kinds of cells, present in the same proportions, but it is easy to refer to illustrations which will serve to identify the kinds of cells found in the studies of the preceding section. They are:

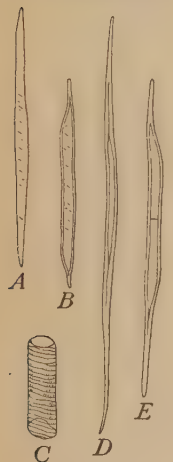


FIG. 59. — *A*, *B*, *C*, *D*, Isolated Wood-Cells and Bast-Cells of Linden.

A, *B*, wood fibers; *C*, piece of a vessel; *D*, bast fiber; *E*, a partitioned, woody fiber from European ivy. (Much magnified.)

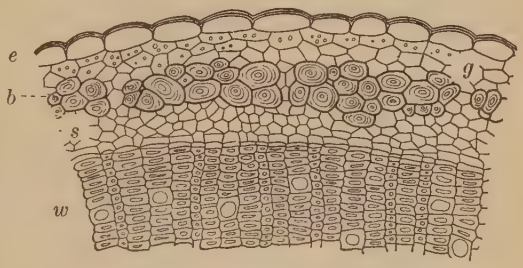


FIG. 60. — Part of Cross-Section of Stem of Flax. (Much magnified.)

e, epidermis; *b*, hard bast; *s*, sieve-cells; *w*, wood.

(1) Cork-cells of the epidermis (*e.g.*, flax, Fig. 60, *e*).

(2) Cells of the green bark (*e.g.*, flax, Fig. 60), between *b* and *e*.

(3) Hard bast (Fig. 60).

(4) Soft bast (*e.g.*, flax, Fig. 60, *s*, for the cross-section and (very greatly magnified) Figs. 63, 64, for the lengthwise section).[1]

[1] The sieve-tubes shown in these figures are only one of several kinds of cell found in soft bast, but they are the most peculiar and characteristic ones. (See Strasburger, Noll, Schenk, and Karsten's *Text-Book*, p. 95.)

(5) Cambium (*e.g.*, Fig. 57, *c*).
(6) Wood-cells (*e.g.*, Figs. 58, 72–73).
(7) Vessels or ducts (*e.g.*, Figs. 58 and 62).
(8) Wood parenchyma (*e.g.*, Figs. 58 and 72 in the medullary rays).
(9) Pith (*e.g.*, Figs. 55, 57).

105. Structure of Coniferous Wood. — In the wood of the cone-bearing trees of the pine family regular ducts or

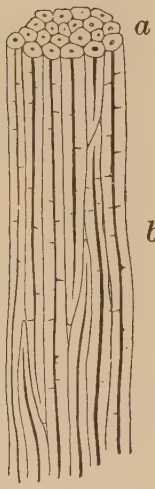


FIG. 61.

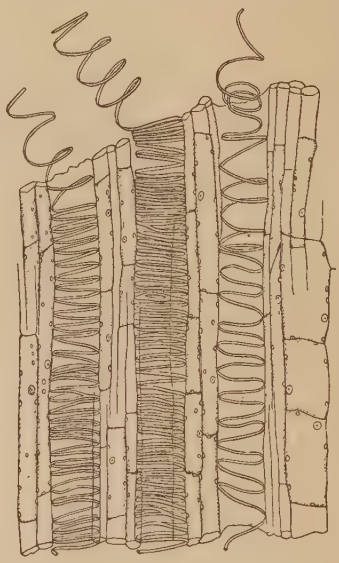


FIG. 62.

FIG. 61. — A Group of Hard Bast Fibers. (Greatly magnified.)

a, cut-off ends; *b*, lengthwise section of fibers.

FIG. 62. — A Lengthwise Section (greatly magnified) of a Group of Spiral Vessels from the Stem of Sunflower. At the top of the figure some of the spiral threads which line the vessels are seen partly uncoiled.

vessels are lacking. The main bulk of the wood is composed of long cells (often called *tracheids*), marked with

peculiar pits. These pits, when young, are shaped much like two perforated watch-glasses, placed against a piece of cardboard, with their concave sides toward each other

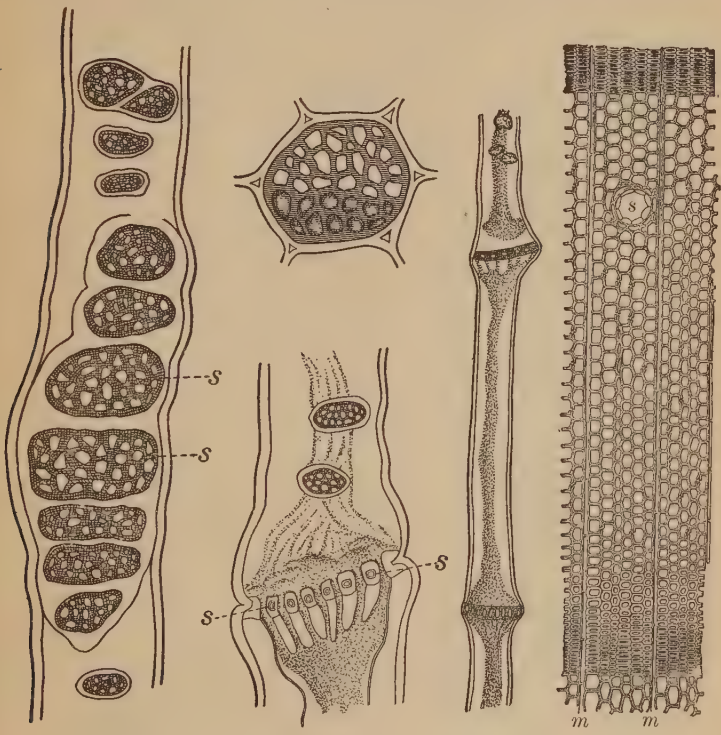


FIG. 63. FIG. 64. FIG. 65.

FIG. 63. — Part of a Sieve-Tube from Linden.

s, sieve-plates on the cell-wall. (× about 900.)

FIG. 64. — Parts of Sieve-Tubes as found in Plants of the Gourd Family. (Greatly magnified.)

s, *s*, a sieve-plate seen edgewise ; above it a similar one, surface view.

FIG. 65. — Cross-Section of Fir Wood.

s, a resin passage ; *m*, medullary rays. (Much magnified.)

(see Fig. 66, t″). The cardboard represents a part of the cell-wall common to two adjacent cells, and the watch-glasses are like the convex border bulging into each cell. When the cells grow old the partition in each pit very commonly breaks away and leaves a hole in the cell-wall.

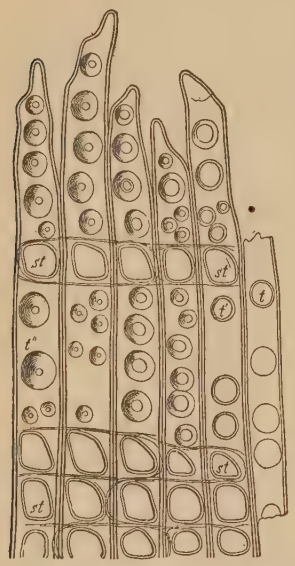


FIG. 66. — Longitudinal Radial Section through a Rapidly Growing Young Branch of Pine.

t, *t′*, *t″*, bordered pits on wood-cells; *st*, large pits where medullary rays lie against wood-cells. (Much magnified.)

106. Tissues. — A mass of similar coöperating cells is called a *tissue*.[1] Two of the principal classes which occur in the stem are *parenchymatous* tissue and *prosenchymatous* tissue. *Parenchyma* is well illustrated by the green layer of the bark, by wood parenchyma, and by pith. Its cells are usually somewhat roundish or cubical, at any rate not many times longer than wide, and at first pretty full of protoplasm. Their walls are not generally very thick.[2] *Prosenchyma*, illustrated by hard bast and masses of wood-cells, consists of thick-walled cells many times longer than wide, containing little protoplasm and often having little or no cell-cavity.

As a rule the stems of the most highly developed plants owe their toughness and their stiffness mainly to prosen-

[1] See Vines' *Students' Text-Book of Botany*, London, 1894, pp. 131–144.

[2] Excepting when they are dead and emptied, like those of old pith.

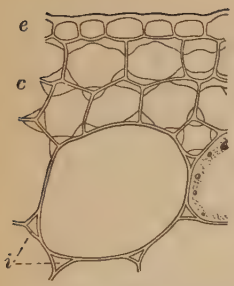


FIG. 67. — Collenchymatous and Other Tissue from Stem of Balsam (*Impatiens*).

e, epidermis; *c*, collenchyma; *i*, intercellular spaces between large parenchyma-cells.

chymatous tissue. In some (particularly in fleshy) stems the stiffness is, however, largely due to *collenchyma*, a kind of parenchyma in which the cells are thickened or reinforced at their angles, as shown in Fig. 67.

107. Early History of Stem-Structure. — In the very young parts of stems, such, for instance, as the growing point between the two rudimentary leaves of a bean-plumule, the cells are all of thin-walled *formative tissue* and look a good deal alike. This condition of things is quickly succeeded by one in which there is a cylinder (appearing in cross-sections of the stem as a ring) of actively growing tissue *x* (Fig. 68, *A*), lying between the cortex *r* and the pith *m*. Soon the cylinder *x* develops into a series of separate fibro-vascular bundles arranged as shown in Fig. 68, *B*, and these again in a short time unite, as shown at *C*. A comparison of this last portion of the figure with that of the

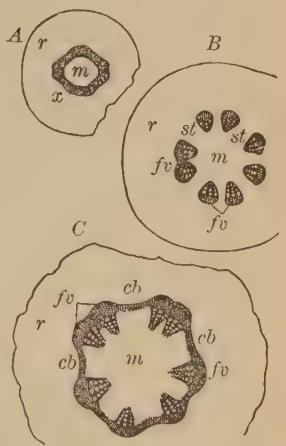


FIG. 68. — Transverse Section through the Hypocotyl of the Castor-Oil Plant at Various Stages.

A, after the root has just appeared outside the testa of the seed; *B*, after the hypocotyl is nearly an inch long; *C*, at the end of germination; *r*, cortex (undeveloped bark); *m*, pith; *st*, medullary rays; *fv*, fibro-vascular bundles; *cb*, layer of tissue which is to develop into cambium. (Considerably magnified.)

one-year-old Aristolochia-stem (Fig. 56) shows a decided similarity between the two. In both cases we have the central pith, the regularly grouped bundles, and cambium (or in Fig. 68, *C*, a tissue which will grow into cambium), — part of it in the bundles and part of it between them.

In the young monocotyledonous stem the grouping of the bundles is less regular than that just explained. This is shown by Fig. 52. A much more important difference consists in the fact that the monocotyledonous stem has usually no permanent living cambium ring. Annual dicotyledons, however, are also destitute of permanent cambium.

108. Secondary Growth. — From the inside of the cambium layer the wood-cells and ducts of the mature stem are produced, while from its outer circumference proceed the new layers of the inner bark, composed largely of sieve-cells and hard bast. From this mode of increase the stems of dicotyledonous plants are called *exogenous*, that is, outside-growing. The presence of the cambium layer on the outside of the wood in early spring is a fact well known to the schoolboy, who pounds the cylinder cut from an elder, willow, or hickory branch until the bark will slip off and so enable him to make a whistle. The sweet taste of this pulpy layer, as found in the white pine, the slippery elm, and the basswood, is a familiar evidence of the nourishment which the cambium layer contains.

With the increase of the fibro-vascular bundles of the wood the space between them, which appears relatively large in Fig. 68, becomes less and less, and the pith, which at first extended freely out toward the circumference of the stem, is at length only represented by thin plates, the medullary rays.

These are of use in storing the food which the plant in cold and temperate climates lays up in the summer and fall for use in the following spring, and in the very young stem they serve as an important channel for the transference of fluids across the stem from bark to pith, or in the

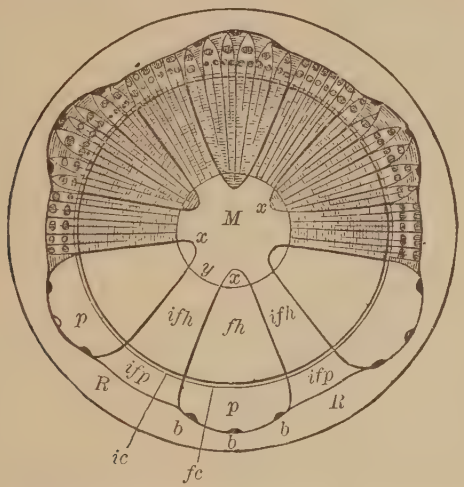


FIG. 69. — Diagram to illustrate Secondary Growth in a Dicotyledonous Stem.

R, the first-formed bark; *p*, mass of sieve-cells; *ifp*, mass of sieve-cells between the original wedges of wood; *fc*, cambium of wedges of wood; *ic*, cambium between wedges; *b*, groups of bast-cells; *fh*, wood of the original wedges; *ifh*, wood formed between wedges; *x*, earliest wood formed; *M*, pith.

reverse direction. On account, perhaps, of their importance to the plants, the cells of the medullary rays are among the longest lived of all plant-cells, retaining their vitality in the beech tree sometimes, it is said, for more than a hundred years.

After the interspaces between the first fibro-vascular bundles have become filled up with wood, the subsequent

growth must take place in the manner shown in Fig. 69. All the cambium, both that of the original wedges of wood, *fc*, and that, *ic*, formed later between these wedges, continues to grow from its inner and from its outer face, and thus causes a permanent increase in the diameter of the stem and a thickening of the bark, which, however, usually at an early period begins to peel off from the outside and thus soon attains a pretty constant thickness.[1] It will be noticed, in the study of dicotyledonous stems more than a year old, that there are no longer any separate fibro-vascular bundles. The process just described has covered the original ring of bundles with layer after layer of later formed wood-cells, and the wood at length is arranged in a hollow cylinder.

It is the lack of any such ring of cambium as is found in dicotyledonous plants, or even of permanent cambium in the separate bundles, that makes it impossible for the trunks of most palm trees (Fig. 54) to grow indefinitely in thickness, like that of an oak or an elm.[2]

109. Grafting. — When the cambium layer of any vigorously growing stem is brought in contact with this layer in another stem of the same kind or a closely similar kind of plant, the two may grow together to form a single stem or branch. This process is called *grafting*, and is much resorted to in order to secure apples, pears, etc., of any desired kind. A twig from a tree of the chosen variety is grafted on to any kind of tree *of the same species* (or sometimes a related species), and the resulting stems will bear the wished-for kind of fruit. Sometimes grafting comes

[1] See Vines' *Students' Text-Book of Botany*, London, 1894, pp. 211, 212.

[2] See, however, Strasburger, Noll, Schenk, and Karsten's *Text-Book*, pp. 144, 145.

about naturally by the branches of a tree chafing against one another until the bark is worn away and the cambium layer of each is in contact with that of the other, or two separate trees may be joined by natural grafting, as is shown in Fig. 70.

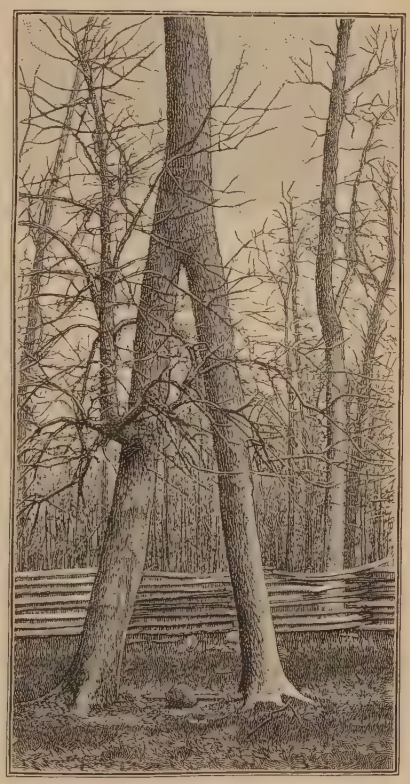


FIG. 70. — Two Ash Trees naturally grafted together.

110. Stem-Structure of Climbing Shrubs. — Some of the most remarkable kinds of dicotyledonous stems are found in climbing shrubs. The structure of many of these is too complicated to be discussed in a botany for beginners, but one point in regard to them is of much interest. The bundles (as seen in the clematis and shown in Fig. 56) are much more distinct than in most other woody stems. Even after several years of growth the wood is often found to be arranged in a number of flattish twisted strands. It is evident that this is for the sake of leaving the stem flexible for twining purposes, just as a wire cable is adapted to be wound about posts or other supports, while

a solid steel or iron rod of the same size would be too stiff for this use.

111. The Dicotyledonous Stem, thickened by Secondary Growth. — Cut off, as smoothly as possible, a small branch of hickory and one of white oak above and below each of the rings of scars already mentioned (Sect. 77), and count the rings of wood above and below each ring of scars.

FIG. 71. — Cross-Section of a Three-Year-Old Linden Twig. (Much magnified.)

P, epidermis and corky layer of the bark; *Phl*, bast; *C*, cambium layer; *JR*, annual rings of wood.

How do the numbers correspond? What does this indicate?

Count the rings of wood on the cut-off ends of large billets of some of the following woods: locust, chestnut, sycamore, oak, hickory.

Do the successive rings of the same tree agree in thickness?

Why? or why not?

Does the thickness of the rings appear uniform all the way round the stick of wood? If not, the reason in the case of an upright stem (trunk) is perhaps that there was a greater spread of leaves on the side where the rings are thickest[1] or because there was unequal pressure, caused by bending before the wind.

Do the rings of any one kind of tree agree in thickness with those of all the other kinds? What does this show?

In all the woods examined look for:

(*a*) Contrasts in color between the heartwood and the sapwood.[2]

[1] See Sect. 118.

[2] This is admirably shown in red cedar, black walnut, barberry, black locust and osage orange.

(*b*) The narrow lines running in very young stems pretty straight from pith to bark, in older wood extending only a little of the way from center to bark, the *medullary rays*, shown in Fig. 72.[1]

(*c*) The wedge-shaped masses of wood between these.

(*d*) The pores which are so grouped as to mark the divisions between successive rings. These pores indicate the cross-sections of *vessels* or *ducts*. Note the distribution of the vessels in the rings to which they belong, compare this with Figs. 58, 72, and decide at what season of the year the largest ducts are mainly produced. Make a careful drawing of the end-section of one billet of wood, natural size.

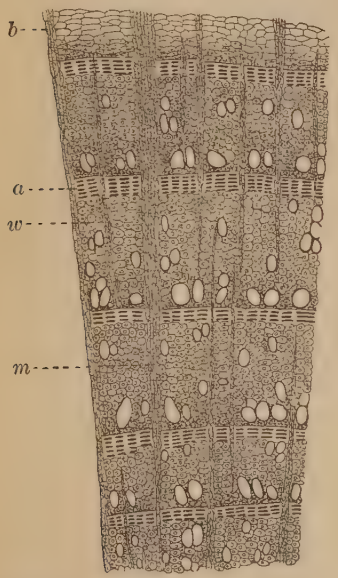


FIG. 72. — Cross-Section of Beech-Wood. *b*, bark; *a*, flattened cells formed near end of each year's growth; *w*, regular wood-cells; *m*, medullary ray.

FIG. 73. — Longitudinal Section of Mahogany at Right Angles to Medullary Rays, showing Cut-off Ends. (Much magnified.)

Cut off a grapevine several years old and notice the great size of

[1] These and many other important things are admirably shown in the thin wood-sections furnished for $4 per set of 24 by R. B. Hough, Lowville, N. Y.

the vessels. Examine the smoothly planed surface of a billet of red oak that has been split through the middle of the tree (quartered oak), and note the large shining plates formed by the medullary rays.

Look at another stick that has been planed away from the outside until a good-sized flat surface is shown, and see how the medullary rays are here represented only by their edges.

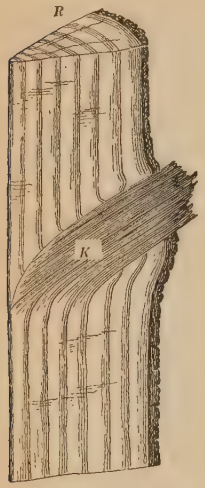


FIG. 74. — Formation of a Knot in a Tree-Trunk.

R, cut-off end of stick, showing annual rings; *K*, knot, formed by growth of a branch.

112. Interruption of Annual Rings by Branches; Knots. — When a leaf-bud is formed on the trunk or branch of a dicotyledonous tree, it is connected with the wood by fibro-vascular bundles. As the bud develops into a branch, the few bundles which it originally possessed increase greatly in number, and at length, as the branch grows, form a cylinder of wood which cuts across the annual rings, as shown in Fig. 74. This interruption to the rings is a knot, such as one often sees in boards and planks. If the branch dies long before the tree does, the knot may be buried under many rings of wood. What is known as clear lumber is obtained from trees that have grown in a dense forest, so that the lower branches of the larger trees were killed by the shade many years before the tree was felled.

In pruning fruit trees or shade trees the branches which are removed should be cut close to the trunk. If this is done, the growth of the trunk will bury the scar before decay sets in.

113. Comparison of the Monocotyledonous and the Dicotyledonous Stem.[1]

	Monocotyledonous Stem	Dicotyledonous Stem
General Structure.	A hard rind of rather uniform structure. Bundles intermixed with the pith.	A complex bark, usually on young shoots consisting of a corky layer, a green layer, and a layer of bast. Wood in annual rings. Pith in a cylinder at the center.
Structure of Bundles.	Bundles *closed*, that is, without permanent cambium.	Bundles *open*, with permanent cambium.
Growth in Thickness.	Cells of mature parts of stem expand somewhat, but (in most palms) new ones are not found.	New wood-cells formed throughout growing season from cambium ring.

114. Review Sketches and Diagrams.

(1) Monocotyledonous stem (lengthwise section).
(2) Dicotyledonous stem (lengthwise section).
(3) First appearance of bundles in dicotyledonous stem.
(4) Dicotyledonous stem five years or more old (cross-section).
(5) Various bark-cells.
(6) Various cells from wood.
(7) Pith-cells.
(8) Collenchyma-cells.

[1] This comparison applies only to most of the woody or tree-like stems.

CHAPTER VII

LIVING PARTS OF THE STEM; WORK OF THE STEM

115. Active Portions of the Stems of Trees and Shrubs. — In annual plants generally and in the very young shoots of shrubs and trees there are *stomata* or breathing pores which occur abundantly in the epidermis, serving for the admission of air and the escape of moisture, while the green layer of the bark answers the same purpose that is served by the green pulp of the leaf (Chapter XI). For years, too, the spongy lenticels, which succeed the stomata and occur scattered over the external surface of the bark of trees and shrubs, serve to admit air to the interior of the stem. The lenticels at first appear as roundish spots, of very small size, but as the twig or shoot on which they occur increases in diameter the lenticel becomes spread out at right angles to the length of the stem, so that it sometimes becomes a longer transverse slit or scar on the bark, as in the cherry and the birch. But in the trunk of a large tree no part of the bark except the inner layer is alive. The older portions of the bark, such as the highly developed cork of the cork-oak, from which the ordinary stoppers for bottles are made, sometimes cling for years after they are dead and useless except as a protection for the parts beneath against mechanical injuries or against cold. But in many cases, as in the shell-bark hickory and the grapevine, the old bark soon falls off in strips; in birches it finally peels off in bands around the stem.

The cambium layer is very much alive, and so is the young outer portion of the wood. Testing this "sap-wood," particularly in winter, shows that it is rich in starch and proteids.

The heartwood of a full-grown tree is hardly living, unless the cells of the medullary rays retain their vitality, and so it may be that wood of this kind is useful to the tree mainly by giving stiffness to the trunk and larger branches, thus preventing them from being easily broken by storms.

It is, therefore, possible for a tree to flourish, sometimes for centuries, after the heartwood has much of it rotted away and left the interior of the trunk hollow, as shown in Fig. 75.

116. Uses of the Components of the Stem. — There is a marked division of labor among the various groups of cells that make up the stem of ordinary dicotyledons, particularly in the stems of trees, and it will be best to explain the uses of the kinds of cells as found in trees, rather than in herbaceous plants. A few of the ascertained uses of the various tissues are these:

The pith forms a large part of the bulk of very young shoots, since it is a part of the tissue of comparatively simple structure amid which the fibro-vascular bundles arise. In mature stems it becomes rather unimportant, though it often continues for a long time to act as a store-house of food.

The medullary rays in the young shoot serve as a channel for the transference of water and plant-food in a liquid form across the stem, and they often contain much stored food.

FIG. 75.—Pioneer's Cabin, a Very Large Hollow Sequoia.

The vessels carry water upward and (sometimes) air downward through the stem.

The wood-cells of the heartwood are useful only to give

stiffness to the stem. Those of the sapwood, in addition to this work, have to carry most of the water from the roots to the leaves and other distant portions of the plant.

The cambium layer is the region in which the annual growth of the tree takes place (Figs. 69, 71).

The most important portion of the inner bark is that which consists of sieve-tubes, for in these digested and elaborated plant-food is carried from the leaves toward the roots.

The green layer of the bark in young shoots does much toward collecting nutrient substances, or raw materials, and preparing the food of the plant from air and water, but this work may be best explained in connection with the study of the leaf (Chapter XI).

117. Movement of Water in the Stem. — The student has already learned that large quantities of water are taken up by the roots of plants.

Having become somewhat acquainted with the structure of the stem, he is now in a position to investigate the question how the various fluids, commonly known as sap, travel about in it.[1] It is important to notice that sap is by no means the same substance everywhere and at all times. As it first makes its way by osmotic action inward through the root-hairs of the growing plant it differs but little from ordinary spring water or well water. The liquid which flows from the cut stem of a "bleeding" grapevine which has been pruned just before the buds have begun to burst in the spring, is mainly water with some organic acids, proteids, and sugar. The sap which is

[1] See the paper on "The So-called Sap of Trees and its Movements," by Professor Charles R. Barnes, *Science*, Vol. XXI, p. 535.

obtained from maple trees in late winter or early spring, and is boiled down for syrup or sugar, is still richer in nutritious material than the water of the grapevine, while the elaborated sap which is sent so abundantly into the ear of corn, at its period of filling out, or into the growing pods of beans and peas, or into the rapidly forming acorn or the chestnut, contains great stores of food, suited to sustain plant or animal life.

EXPERIMENT XXI

Rise of Water in Stems. — Cut some short branches from an apple tree or a cherry tree and stand the lower end of each in red ink; try the same experiment with twigs of oak, ash, or other porous wood, and after some hours[1] examine with the magnifying glass and with the microscope, using the 2-inch objective, successive cross-sections of one or more twigs of each kind. Note exactly the portions through which the ink has traveled. Pull off the leaves from one of the stems after standing in the eosin solution, and notice the spots on the leaf-scar through which the eosin has traveled. These spots show the positions of the *leaf-traces*, or fibro-vascular bundles, connecting the stem and the leaf. Repeat with several potatoes, cut crosswise through the middle. Try also some monocotyledonous stems, such as those of the lily or asparagus. For the sake of comparison between roots and stems, treat any convenient root, such as a parsnip, in the same way.

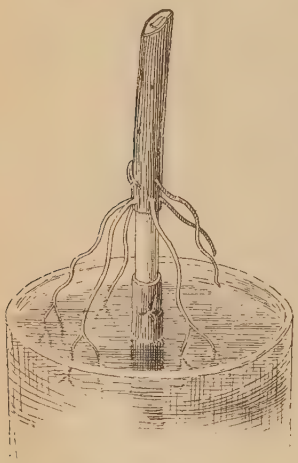


FIG. 76. — A Cutting girdled and sending down Roots from the Upper Edge of the Girdled Ring.

[1] If the twigs are leafy and the room is warm, only from 5 to 30 minutes may be necessary.

Examine longitudinal sections of some of the twigs, the potatoes, and the roots. In drawing conclusions about the channels through which the ink has risen (those through which the newly absorbed soil-water most readily travels), bear in mind the fact that a slow soakage of the red ink will take place in all directions, and therefore pay attention only to the strongly colored spots or lines.

What conclusions can be drawn from this experiment as to the course followed by the sap?

FIG. 77. — Channels for the Movement of Water, upward and downward.

The heavy black lines in roots, stems, and leaves show the course of the fibro-vascular bundles through which the principal movements of water take place.

From the familiar facts that ordinary forest trees apparently flourish as well after the almost complete decay and removal of their heartwood, and that many kinds will live and grow for a considerable time after a ring of bark extending all round the trunk has been removed, it may readily be inferred that the crude sap in trees must rise through some portion of the newer layers of the wood. A tree girdled by the removal of a ring of sapwood promptly dies.

118. Downward Movement of Liquids. — Most dicotyledonous stems, when stripped of a ring of bark and then

stood in water, as shown in Fig. 76, and covered with a bell-jar, develop roots only at or near the upper edge of the stripped portion,[1] and this would seem to prove that such stems send their building material — the elaborated sap — largely at any rate down through the bark. Its course is undoubtedly for the most part through the sieve-cells (Figs. 63, 64), which are admirably adapted to convey liquids. In addition to these general upward and downward movements of sap, there must be local transfers laterally through the stem, and these are at times of much importance to the plant.

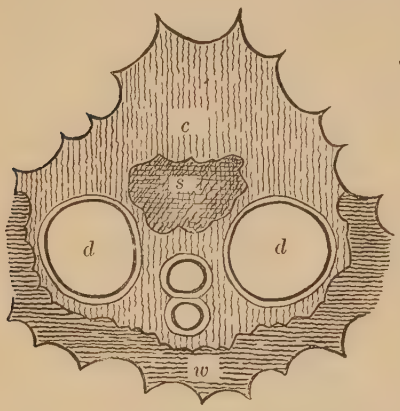


FIG. 78. — Diagrammatic Cross-Section of a Bundle from Sugar-Cane, showing Channels for Food and Water. (Magnified.)

c, bast fibers and wood parenchyma; *d*, ducts; *s*, sieve tubes; *w*, wood fibers. Water travels upward through the ducts and through the wood-cells in the region marked *w*. Water with dissolved plant-food travels downward through the sieve-cells in the region marked *s*.

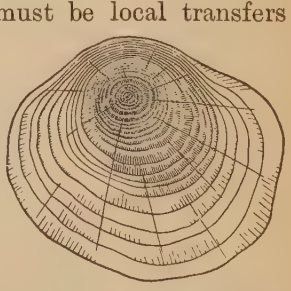


FIG. 79. — Unequal Growth of Rings of Wood in nearly Horizontal Stem of a Juniper. (Natural size.)

Often the liquid building material is rather equally distributed around the growing zone of the stem. This results in nearly uniform growth on all sides. But sometimes, from imperfectly

[1] This may be made the subject of a protracted class-room experiment. Strong shoots of willow should be used for the purpose.

explained causes, the material is unequally distributed, so that the annual rings are irregular (Fig. 79). In nearly horizontal branches either the top or the bottom may grow faster.

119. Rate of Movement of Water in the Stem. — There are many practical difficulties in the way of ascertaining exactly how fast the watery sap travels from the root to the leaves. It is, however, easy to illustrate experimentally the fact that it does rise, and to give an approximate idea of the time required for its ascent. The best experiment for beginners is one which deals with an entire plant under natural conditions.

EXPERIMENT XXII

Wilting and Recovery. — Allow a fuchsia or a hydrangea[1] which is growing in a flower-pot to wilt considerably for lack of watering. Then water it freely and record the time required for the leaves to begin to recover their natural appearance and position, and the time fully to recover.

The former interval of time will give a very rough idea of the time of transfer of water through the roots and the stem of the plant. From this, by measuring the approximate distance traveled, a calculation could be made of the number of inches per minute that water travels in this particular kind of plant, through a route which is partly roots, partly stem, and partly petiole. Still another method is to treat leafy stems as the student in Exp. XXI treated the twigs which he was examining, and note carefully the rate of ascent of the coloring liquid. This plan is likely to give results that are too low, still it is of some use. It has given results varying from 34 inches per

[1] *Hydrangea Hortensia.*

hour for the willow to 880 inches per hour for the sunflower. A better method is to introduce the roots of the plant which is being experimented upon into a weak solution of some chemical substance which is harmless to the plant and which can readily be detected anywhere in the tissues of the plant by chemical tests. Proper tests are then applied to portions of the stem which are cut from the plant at short intervals of time.

Compounds of the metal lithium are well adapted for use in this mode of experimentation.

120. Causes of Movements of Water in the Stem. — Some of the phenomena of osmosis were explained in Sect. 62, and the work of the root-hairs was described as due to osmotic action.

Root-pressure (Sect. 66), being apparently able to sustain a column of water only 80 or 90 feet high at the most, and usually less than half this amount, would be quite insufficient to raise the sap to the tops of the tallest trees, since many kinds grow to a height of more than 100 feet. Our Californian "big trees," or Sequoias, reach the height of over 300 feet, and an Australian species of Eucalyptus, it is said, sometimes towers up to 470 feet. Root-pressure, then, may serve to start the soil-water on its upward journey, but some other force or forces must step in to carry it the rest of the way. What these other forces are is still a matter of discussion among botanists.

The slower inward and downward movement of the sap may be explained as due to osmosis. For instance, in the case of growing wood-cells, sugary sap descending from the leaves into the stem gives up part of its sugar to form the cellulose of which the wood-cells are being made.

This loss of sugar would leave the sap rather more watery than usual, and osmosis would carry it from the growing wood to the leaves, while at the same time a slow transfer of the dissolved sugar will be set up from leaves to wood. The water, as fast as it reaches the leaves, will be thrown off in the form of vapor, so that they will not become distended with water, while the sugar will be changed into cellulose and built into new wood-cells as fast as it reaches the region where such cells are being formed.

Plants in general[1] readily change starch to sugar, and sugar to starch. When they are depositing starch in any part of the root or stem for future use, the withdrawal of sugar from those portions of the sap which contain it most abundantly gives rise to a slow movement of dissolved particles of sugar in the direction of the region where starch is being laid up.

121. Storage of Food in the Stem. — The reason why the plant may profit by laying up a food supply somewhere inside its tissues has already been suggested (Sect. 91).

The most remarkable instance of storage of food in the stem is probably that of sago-palms, which contain an enormous amount, sometimes as much as 800 pounds, of starchy material in a single trunk. But the commoner plants of temperate regions furnish plenty of examples of deposits of food in the stem. As in the case of seeds and roots, starch constitutes one of the most important kinds of this reserve material of the stem, and since it is easier to detect than any other food material which the plant stores, the student will do well to spend time in looking for starch only.

[1] Not including most of the flowerless and very low and simple kinds.

Cut thin cross-sections of twigs of some common deciduous tree or shrub, in its early winter condition, moisten with iodine solution, and examine for starch with a moderately high power of the microscope. Sketch the section with a pencil, coloring the starchy portions with blue ink, used with a mapping pen, and describe exactly in what portions the starch is deposited.

122. Storage in Underground Stems. — The branches and trunk of a tree furnish the most convenient place in which to deposit food during winter to begin the growth of the following spring. But in those plants which die down to the ground at the beginning of winter the storage must be either in the roots, as has been described in Sect. 58, or in underground portions of the stem.

Rootstocks, tubers, and bulbs seem to have been developed by plants to answer as storehouses through the winter (or in some countries through the dry season) for the reserve materials which the plant has accumulated during the growing season. The commonest tuber is the potato, and this fact and the points of interest which it represents make it especially desirable to use for a study of the underground stem in a form most highly specialized for the storage of starch and other valuable products.

123. A Typical Tuber: the Potato. — Sketch the general outline of a potato, showing the attachment to the stem from which it grew.[1]

Note the distribution of the "eyes," — are they opposite or alternate? Examine them closely with the magnifying glass and then with the lowest power of the microscope. What do they appear to be?

If the potato is a stem, it may branch, — look over a lot of potatoes to try to find a branching specimen. If such a one is secured, sketch it.

[1] Examination of a lot of potatoes will usually discover specimens with an inch or more of attached stem.

Note the little scale overhanging the edge of the eye, and see if you can ascertain what this scale represents.

Cut the potato across, and notice the faint broken line which forms a sort of oval figure some distance inside the skin.

Place the cut surface in eosin solution, allow the potato to stand so for many hours, and then examine, by slicing off pieces parallel to the cut surface, to see how far and into what portions the solution has penetrated. Refer to the notes on the study of the parsnip (Sect. 56), and see how far the behavior of the potato treated with eosin solution agrees with that of the parsnip so treated.

Cut a thin section at right angles to the skin, and examine with a high power. Moisten the section with iodine solution and examine again.

If possible, secure a potato which has been sprouting in a warm place for a month or more (the longer the better), and look near the origins of the sprouts for evidences of the loss of material from the tuber.

EXPERIMENT XXIII

Use of the Corky Layer. — Carefully weigh a potato, then pare another larger one, and cut portions from it until its weight is made approximately equal to that of the first one. Expose both freely to the air for some days and reweigh. What does the result show in regard to the use of the corky layer of the skin?

124. Morphology of the Potato. — It is evident that in the potato we have to do with a very greatly modified form of stem. The corky layer of the bark is well represented, and the loose cellular layer beneath is very greatly developed; wood is almost lacking, being present only in the very narrow ring which was stained by the red ink, but the pith is greatly developed and constitutes the principal bulk of the tuber. All this is readily understood if we consider that the tuber, buried in and supported by the earth, does not need the kinds of tissue which give

strength, but only those which are well adapted to store the requisite amount of food.

125. Structure of a Bulb; the Onion. — Examine the external appearance of the onion and observe the thin membranaceous skin which covers it. This skin consists of the broad sheathing bases of the outer leaves which grew on the onion plant during the summer. Remove these and notice the thick scales (also formed from bases of leaves as shown in Fig. 48) which make up the substance of the bulb.

Make a transverse section of the onion at about the middle and sketch the rings of which it is composed. Cut a thin section from the interior of the bulb, examine with a moderate power of the microscope, and note the thin-walled cells of which it is composed.

Split another onion from top to bottom and try to find:

(*a*) The *plate* or broad flattened stem inside at the base (Fig. 47).

(*b*) The central bud.

(*c*) The bulb-scales.

(*d*) In some onions (particularly large, irregular ones) the bulblets or side buds arising in the axes of the scales near the base.

Test the cut surface for starch.

126. Sugar in the Onion. — *Grape sugar* is an important substance among those stored for food by the plant. It received its name from the fact that it was formerly obtained for chemical examination from grapes. Old dry raisins usually show little masses of whitish material scattered over the skin which are nearly pure grape sugar. Commercially it is now manufactured on an enormous scale from starch by boiling with diluted sulphuric acid. In the plant it is made from starch by processes as yet imperfectly understood, and another sugar, called *maltose*, is made from starch in the seed during germination.

Both grape sugar and maltose (and hardly any other substances) have the power of producing a yellow or

orange color and throwing down an orange or reddish deposit, when they are added to a brilliant blue alkaline solution of copper, known as *Fehling's solution*.[1] The color or deposit will not appear until the solution has been heated to boiling.

EXPERIMENT XXIV

Testing for Grape Sugar. — Heat to boiling in a test-tube or a small beaker some weak syrup of grape sugar or some honey, much diluted with water. Add Fehling's solution, a few drops at a time, until a decided orange color appears. Repeat the test with the water in which some slices of onion have been boiled, filtering the water through a paper filter and heating again to boiling before adding the test solution.[2]

127. Proteids in the Onion. — Since the onion grows so rapidly on being planted in the spring, there must be a large supply of food in the bulb; there may be other substances present besides sugar.

EXPERIMENT XXV

Testing an Onion for Other Stored Food. — Test a rather thick slice of onion by heating it in a porcelain evaporating dish with a little strong nitric acid until the latter begins to boil and the onion becomes somewhat softened.[3] Rinse off the slice of onion in a stream of water, then pour on it a few drops of ammonium hydrate and observe any change of color. What is proved? See Sect. 29.

128. Tabular Review of Experiments.

[Continue the table from Sect. 74.]

[1] For the preparation of the solution see Handbook.

[2] The deposit will in this case, even if orange at first, finally become black, probably owing to the presence of sulphur in the onion.

[3] Do not allow the acid to touch the clothing, the hands, or any metallic object.

129. Review Summary of Work of Stem.

- Channels for upward movement of water
  - in young dicotyledonous stems .
  - in dicotyledonous stems several years old . . . . . .
  - in monocotyledonous stems . .
- Channels for downward movement of water
  - in dicotyledonous stems . . .
  - in monocotyledonous stems . .
- Channels for transverse movements . . . . . .
- Rate of upward movement . . . . . .
- Storage of plant-food
  - where stored . . . . . .
  - kinds stored . . . . . .
  - uses . . . . . .

CHAPTER VIII

BUDS

130. Structure of Buds. — While studying twigs in their winter condition, as directed in Sects. 77, 78, the student had occasion to notice the presence, position, and arrangement of buds on the branch, but he was not called upon to look into the details of their structure. The most natural time to do this is just before the study of the leaf is begun, since leafy stems spring from buds, and the rudiments of leaves in some form must be found in buds.

131. The Horse-Chestnut Bud. — Examine one of the lateral buds on a twig in its winter or early spring condition.[1]

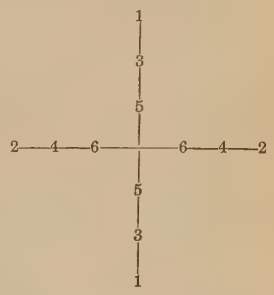
Make a sketch of the external appearance of the buds as seen with a magnifying glass.

How do the scales with which it is covered lie with reference to those beneath them?

Notice the sticky coating on the scales.

Are the scales opposite or alternate?

Remove the scales in pairs, placing them in order on a sheet of paper, thus:



Make the distance from 1 to 1 as much as 6 or 8 inches.

How many pairs are found?

Observe as the scales are removed whether the sticky coating is

[1] The best possible time for this examination is just as the buds are beginning to swell slightly in the spring. The bud of buckeye or of cottonwood will do for this examination, though each is on a good deal smaller scale than the horse-chestnut bud. Buds may be forced to open early by placing twigs in water in a very warm, light place for many weeks.

thicker on the outside or the inside of each scale, and whether it is equally abundant on all the successive pairs.

What is the probable use of this coating?

Note the delicate veining of some of the scales as seen through the magnifying glass. What does this mean?

FIG. 80. — Dissected Bud of Buckeye (*Æsculus macrostachya*), showing Transitions from Bud-Scales to Leaves.

Inside the innermost pair are found two forked woolly objects; what are these?

Compare with Figs. 87 and 107.

Their shape could be more readily observed if the woolly coating were removed.

Can you suggest a use for the woolly coating?

Examine a terminal bud in the same way in which you have just studied the lateral bud.

Does it contain any parts not found in the other?

What is the appearance of these parts?

What do they represent?

If there is any doubt about their nature, study them further on a horse-chestnut tree during and immediately after the process of leafing out in the spring.

For comparison study at least one of the following kinds of buds in their winter or early spring condition: hickory, butternut, beech, ash, magnolia (or tulip tree), lilac, balm of Gilead, cottonwood, cultivated cherry.[1]

[1] Consult the account of the mode of studying buds in Professor W. F. Ganong's *Teaching Botanist*, pp. 208–210. If some of the buds are studied at home, pupils will have a better chance to examine at leisure the unfolding process.

132. Nature of Bud-Scales. — The fact that the bud-scales are in certain cases merely imperfectly developed leaves or leaf-stalks is often clearly manifest from the series of steps connecting the bud-scale on the one hand with the young leaf on the other, which may be found in many opening buds, as illustrated by Fig. 80. In other buds the scales are not imperfect leaves, but the little appendages (*stipules*, Figs. 98, 99) which occur at the bases of leaves. This kind of bud-scale is especially well shown in the magnolia and the tulip tree.

133. Naked Buds. — All of the buds above mentioned are *winter buds*, capable of living through the colder months of the year, and are scaly buds.

In the herbs of temperate climates, and even in shrubs and trees of tropical regions, the buds are often *naked*, that is, nearly or quite destitute of scaly coverings (Fig. 81).

Make a study of the naked buds of any convenient herb, such as one of the common "geraniums" (*Pelargonium*), and record what you find in it.

FIG. 81. — Tip of Branch of *Ailanthus* in Winter Condition, showing very Large Leaf-Scars and nearly Naked Buds.

134. Position of Buds. — The distinction between *lateral* and *terminal* buds has already been alluded to.

The plumule is the first terminal bud which the plant produces. Lateral buds are usually *axillary*, as shown in Fig. 82, that is, they grow in the angle formed by the leaf with the stem (Latin *axilla*, armpit). But not infrequently there are several buds grouped in some way about

FIG. 82. — Alternate Leaves of Cultivated Cherry, with Buds in their Axils, in October.

a single leaf-axil, either one above the other, as in the butternut (Fig. 84), or grouped side by side, as in the red maple, the cherry, and the box-elder (Fig. 83).

In these cases all the buds except the axillary one are called *accessory* or *supernumerary* buds.

135. Leaf-Buds and Flower-Buds; the Bud an Undeveloped Branch. — Such buds as the student has so far

examined for himself are not large enough to show in the most obvious way the relation of the parts and their real nature.

Fortunately, it is easy to obtain a gigantic terminal bud which illustrates perfectly the structure and arrangement of the parts of buds in general.

Examine and sketch a rather small, firm cabbage, preferably a red one, which has been split lengthwise through the center[1] and note

(*a*) The short, thick, conical stem.

(*b*) The crowded leaves which arise from the stem, the lower and outer ones largest and most mature, the upper and innermost ones the smallest of the series.

(*c*) The axillary buds, found in the angles made by some leaves with the stem.

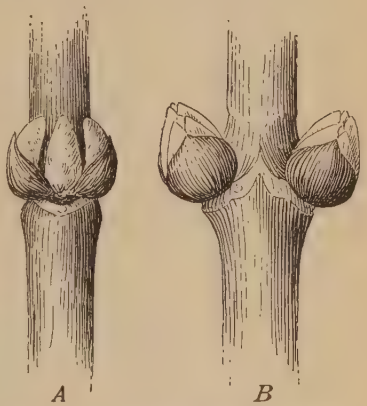


FIG. 83. — Accessory Buds of Box-Elder (*Negundo*). (Magnified.)

A, front view of group.
B, two groups seen in profile.

Compare the section of the cabbage with Fig. 86.

Most of the buds so far considered were *leaf-buds*, that is, the parts inside of the scales would develop into leaves, and their central axes into stems; but some were *mixed buds*, that is, they contained both leaves and flowers in an undeveloped condition.

Flower-buds contain the rudiments of flowers only.

Sometimes, as in the black walnut and the butternut, the leaf-buds and flower-buds are readily distinguishable

[1] Half of a cabbage will be enough for the entire division.

by their difference in form, while in other cases, as in the cultivated cherry, the difference in form is but slight.

The rings of scars about the twig, shown in Figs. 82 and 85, mark the place where the bases of bud-scales were attached. A little examination of the part of the twig which lies outside of this ring, as shown in Fig. 82, will lead one to the conclusion that this portion has all grown in the one spring and summer since the bud-scales of that particular ring dropped off. Following out this suggestion, it is easy to reckon the age of any moderately old portion of a branch, since it is equal to the number of segments between the rings. In rapidly growing shoots of willow, poplar, and similar trees, 5 or 10 feet of the length may be the growth of a single year, while in the lateral twigs of the hickory, apple, or cherry the yearly increase may be but a fraction of an inch. Such fruiting "spurs" as are shown in Fig. 85 are of little use in the permanent growth of the tree, and poplars, elms, soft maples and other trees shed the oldest of these every year. Whatever the amount of this growth, it is but the lengthening out and development of the bud, which may be regarded as an undeveloped stem or branch, with its internodes so shortened that successive leaves seem almost to spring from the same point.

FIG. 84. — Accessory Buds of Butternut. (Reduced.)

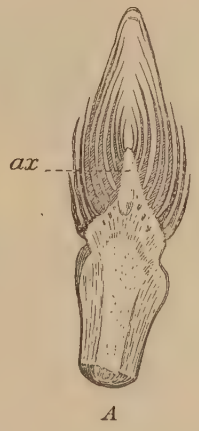
l, leaf-scar; *ax*, axillary bud; *a*, *a'*, accessory buds; *t*, terminal bud.

136. Vernation. — Procure a considerable number of buds which are just about to burst, and others which have begun to open. Cut each across with a razor or very sharp scalpel; examine first with the magnifying glass, and then with the lowest power of the microscope. Pick to pieces other buds of the same kinds under the magnifying glass, and report upon the manner in which the leaves are packed away.

The arrangement of leaves in the bud is called *vernation;* some of the principal modes are shown in Fig. 86.

FIG. 85. — A slowly grown Twig of Cherry, 3 inches long and about ten years old.

The pointed bud *l* is a leaf-bud; the more obtuse accessory buds *f*, *f* are flower-buds.



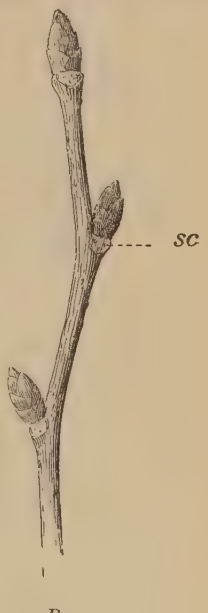


FIG. 86.

B, a twig of European elm; *A*, a longitudinal section of the buds of *B* (considerably magnified); *ax*, the axis of the bud, which will elongate into a shoot; *sc*, leaf-scars.

In the cherry the two halves of the leaf are folded together flat, with the under surfaces outward; in the walnut the separate *leaflets*, or parts of the leaf, are folded

flat and then grouped into a sort of cone; in the snowball each half of the leaf is plaited in a somewhat fan-like manner, and the edges of the two halves are then brought round so as to meet; in the lady's mantle the fan-like plaiting is very distinct; in the wood sorrel each leaflet

FIG. 87, I.—Types of Vernation.
1, 2, Cherry; 3, 4, European walnut; 5, 6, snowball; 7, lady's mantle; 8, oxalis.

is folded smoothly, and then the three leaflets packed closely side by side. All these modes of vernation and many others have received accurate descriptive names by which they are known to botanists.

137. Importance of Vernation. —The significance of vernation is best understood by considering that there are two

important purposes to be served; the leaves must be stowed as closely as possible in the bud, and upon beginning to open they must be protected from too great heat and dryness until they have reached a certain degree of firmness. It may be inferred from Fig. 87, I, that it is common for very young leaves to stand vertically. This protects them considerably from the scorching effect of the sun at the hottest part of the day. Many young leaves, as, for instance, those of the silver-leafed poplar, the pear, the beech, and the mountain ash, are sheltered and pro-

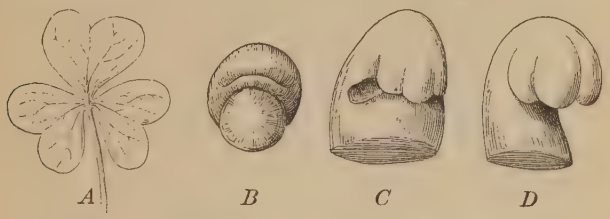


FIG. 87, II. — Development of an Oxalis Leaf.

A, full-grown leaf; *B*, rudimentary leaf, the leaflets not yet evident; *C*, more advanced stage, the leaflets appearing; *D*, a still more advanced stage; *B*, *C*, and *D*, considerably magnified.

tected from the attacks of small insects by a coating of wool or down, which they afterwards lose. Those of the tulip tree are enclosed for a little time in thin pouches, which serve as bud-scales, and thus entirely shielded from direct contact with the outside air (see Sect. 117).

138. Dormant Buds. — Generally some of the buds on a branch remain undeveloped in the spring, when the other buds are beginning to grow, and this inactive condition may last for many seasons. Finally the bud may die, or some injury to the tree may destroy so many other buds as to leave the dormant ones an extra supply of food, and

this, with other causes, may force them to develop and to grow into branches.

Sometimes the tree altogether fails to produce buds at places where they would regularly occur. In the lilac the terminal bud usually fails to appear, and the result is constant forking of the branches.

139. Adventitious Buds. — Buds which occur in irregular places, that is, not terminal nor in or near the axils of leaves, are called *adventitious buds;* they may spring from the roots, as in the silver-leafed poplar, or from the sides of the trunk, as in our American elm. In many trees, for instance willows and maples, they are sure to appear after the trees have been cut back. Willows are thus cut back or *pollarded*, as shown in Plate II, in order to cause them to produce a large crop of slender twigs suitable for basket-making.

Leaves rarely produce buds, but a few kinds do so when they are injured. Those of the bryophyllum, a plant allied to the garden live-for-ever, when they are removed from the plant while they are still green and fresh, almost always send out buds from the margin. These do not appear at random but are borne at the notches in the leaf-margin and are accompanied almost from the first by minute roots.

Pin up a bryophyllum leaf on the wall of the room or lay it on the surface of moist earth, and follow, day by day, the formation and development of the buds which it may produce.

This plant seems to rely largely upon leaf-budding to reproduce itself, for in a moderately cool climate it rarely flowers or seeds, but drops its living leaves freely, and from each such leaf one or several new plants may be produced.

PLATE II. — Pollarded Willows

140. Review Summary of Chapter VIII.

- Buds
  - Coverings . . . . . .
  - Contents . .
    - leaf-buds . . . . . .
    - flower-buds . . . . . .
    - mixed buds . . . . . .
- Classes of buds as regards position . .
  - regular
  - irregular . . . . . .

Make a sketch of Fig. 82 as it looked in June of the same summer; also as it would look the following June. Sketch the twigs of Fig. 30 and Fig. 86 as seen one year later.

CHAPTER IX

LEAVES

141. The Elm Leaf. — Sketch the leafy twig of elm that is supplied to you.[1]

Report on the following points:

(*a*) How many rows of leaves?

(*b*) How much overlapping of leaves when the twig is held with the upper sides of the leaves toward you? Can you suggest a reason for this? Are the spaces between the edges of the leaves large or small compared with the leaves themselves?

Pull off a single leaf and make a very careful sketch of its under surface, about natural size. Label the broad expanded part the *blade*, and the stalk by which it is attached to the twig, *leaf-stalk* or *petiole*.

Study the outline of the leaf and answer these questions:

(*a*) What is the shape of the leaf taken as a whole? (See Fig. 88.) Is the leaf *bilaterally symmetrical*, *i.e.*, is there a middle line running through it lengthwise, along which it could be so folded that the two sides would precisely coincide?

(*b*) What is the shape of the tip of the leaf? (See Fig. 89.)

(*c*) Shape of the base of the leaf? (See Fig. 90.)

(*d*) Outline of the margin of the leaf? (See Fig. 93.)

Notice that the leaf is traversed lengthwise by a strong *midrib* and that many so-called *veins* run from this to the margin. Are

[1] Any elm will answer the purpose. Young strong shoots which extend horizontally are best, since in these leaves are most fully developed and their distribution along the twig appears most clearly. Other good kinds of leaves with which to begin the study, if elm leaves are not available, are those of beech, oak, willow, peach, cherry, apple. Most of the statements and directions above given would apply to any of the leaves just enumerated. If this chapter is reached too early in the season to admit of suitable material being procured for the study of leaf arrangement, that topic may be omitted until the leaves of forest trees have sufficiently matured.

FIG. 88. — General Outline of Leaves.

a, linear; *b*, lanceolate; *c*, wedge-shaped; *d*, spatulate; *e*, ovate; *f*, obovate; *g*, kidney-shaped; *h*, orbicular; *i*, elliptical.

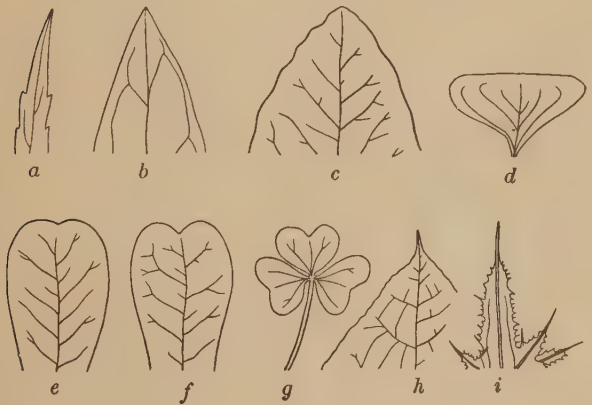


FIG. 89. — Tips of Leaves.

a, acuminate or taper-pointed; *b*, acute; *c*, obtuse; *d*, truncate; *e*, retuse; *f*, emarginate or notched; *g* (end leaflet), obcordate; *h*, cuspidate, — the point sharp and rigid; *i*, mucronate, — the point merely a prolongation of the midrib.

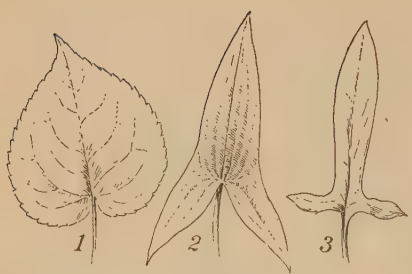


FIG. 90. — Shapes of Bases of Leaves.

1, heart-shaped (unsymmetrically); 2, arrow-shaped; 3, halberd-shaped.

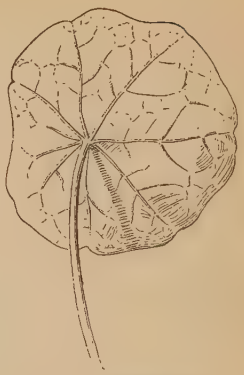


FIG. 91. — Peltate Leaf of Tropæolum.

FIG. 92.

A, runcinate leaf of dandelion; *B*, lyrate leaf.

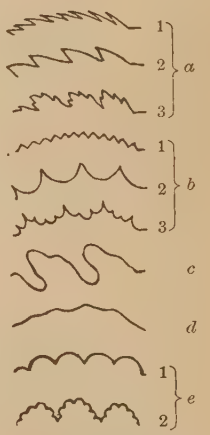


FIG. 93. — Shapes of Margins of Leaves.

a (1), finely serrate; (2), coarsely serrate; (3), doubly serrate. *b* (1), finely dentate; (2), sinuate dentate; (3), doubly dentate. *c*, deeply sinuate. *d*, wavy. *e* (1), crenate or scalloped; (2), doubly crenate.

these veins parallel? how the main veins

Hold the leaf up towards the light and see are connected by smaller *veinlets*. Examine with your glass the leaf as held to the light and make a careful sketch of portions of one or two veins and the intersecting veinlets. How is the course of the veins shown on the upper surface of the leaf?

Examine both surfaces of the leaf with the glass and look for hairs distributed on the surfaces. Describe the manner in which the hairs are arranged.

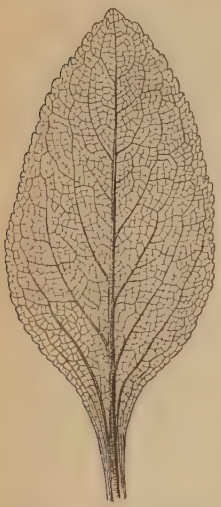


FIG. 94.—Netted Veining (pinnate) in the Leaf of the Foxglove.

The various forms of leaves are classed and described by botanists with great minuteness,[1] not simply for the study of leaves themselves, but also because in classifying and describing plants the characteristic forms of the leaves of many kinds of plants form a very simple and ready means of distinguishing them from each other and identifying them. The student is not expected to learn the names of the several shapes of leaves as a whole or of their bases, tips, or margins, except in those cases in which he needs to use and apply them.

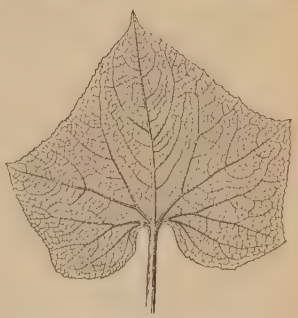


FIG. 95.—Netted Veining (palmate) in Leaf of Melon.

Many of the words used to describe the shapes of leaves are equally applicable to the leaf-like parts of flowers.

[1] See Kerner and Oliver's *Natural History of Plants*, Vol. I, pp. 623–637.

142. The Maple Leaf. — Sketch the leafy twig.

Are the leaves arranged in rows like those of the elm? How are they arranged?

How are the petioles distorted from their natural positions to bring the proper surface of the leaf upward toward the light?

Do the edges of these leaves show larger spaces between them than the elm leaves did, *i.e.*, would a spray of maple intercept the sunlight more or less perfectly than a spray of elm? Pull off a single leaf and sketch its lower surface, about natural size.

FIG. 96. — Pinnately Divided Leaf of Celandine.

The blade of the leaf is discontinuous, consisting of several portions between which are spaces in which one part of the blade has been developed.

Of the two main parts whose names have already been learned (blade and petiole), which is more developed in the maple than in the elm leaf?

Describe:

(*a*) The shape of the maple leaf as a whole. To settle this, place the leaf on paper, mark the positions of the extreme points and connect these by a smooth line.

(*b*) Its outline as to main divisions: of what kind and how many.

(*c*) The detailed outline of the margin (Fig. 93).

Compare the mode of veining or venation of the elm and the maple leaf by making a diagram of each.

These leaves agree in being *netted-veined; i.e.*, in having veinlets that join each other at many angles, so as to form a sort of delicate lace-work, like Figs. 94 and 95.

They differ, however, in the arrangement of the principal veins. Such a leaf as that of the elm is said to be feather-veined, or *pinnately veined.*

The maple leaf, or any leaf with closely similar venation, is said to be *palmately veined.* Describe the difference between the two plans of venation.

143. Relation of Venation to Shape of Leaves. — As soon as the student begins to observe leaves somewhat widely,

he can hardly fail to notice that there is a general relation between the plan of venation and the shape of the leaf. How may this relation be stated? In most cases the principal veins follow at the outset a pretty straight course, a fact for which the student ought to be able to give a reason after he has performed Exp. XXXII.

On the whole, the arrangement of the veins seems to be such as to stiffen the leaf most in the parts that need most support, and to reach the region near the margin by as short a course as possible from the end of the petiole.

Fig. 97. — Palmately Divided Leaf of Buttercup.

Fig. 98. — Leaf of Apple, with Stipules.

Fig. 99. — Leaf of Pansy, with Leaf-Like Stipules.

144. Stipules. — Although they are absent from many leaves, and disappear early from others, *stipules* form a part (sometimes the largest and most useful portion) of the leaf.[1] When present they are sometimes found as little

[1] Unless the elm twigs used in the previous study were cut soon after the unfolding of the leaves in spring, the stipules may not have been left in any recognizable shape.

bristle-shaped objects at the base of the leaf, as in the apple leaf (Fig. 98), sometimes as leaf-like bodies, for example in the pansy (Fig. 99), and in many other forms, one of which is that of spinous appendages, as shown in the common locust (Fig. 103).

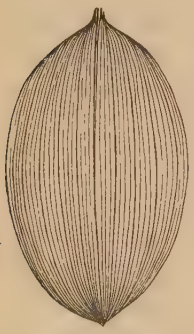


FIG. 100. — Parallel-Veined Leaf of Solomon's Seal.

145. Parallel-Veined Leaves. — The leaves of many great groups of plants, such as the lilies, the sedges, and the grasses, are commonly *parallel-veined*, that is, with the veins running nearly parallel, lengthwise through the blade, as shown in Fig. 100, or with parallel veins proceeding from a midrib and thence extending to the margin, as shown in Fig. 101.

146. Occurrence of Netted Veining and of Parallel Veining. — The student has already, in his experiments on germination, had an opportunity to observe the difference in mode of veining between the leaves of some dicotyledonous plants and those of monocotyledonous plants. This difference is general throughout these great groups of flowering plants. What is the difference?

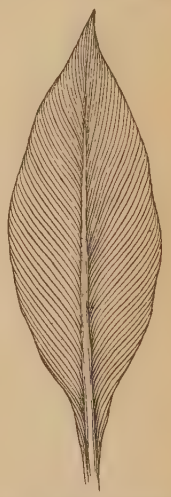


FIG. 101. — Parallel Veining in Canna. Veins running from midrib to margin.

The polycotyledonous pines, spruces, and other coniferous trees have leaves with but a single vein, or two or three parallel ones, but in their case the veining could hardly be other than parallel, since the needle-like leaves are so

narrow that no veins of any considerable length could exist except in a position lengthwise of the leaf.

The fact that a certain plan of venation is found mainly in plants with a particular mode of germination, of stem structure, and of arrangement of floral parts, is but one of the frequent cases in botany in which the structures of plants are correlated in a way which it is not easy to explain.

FIG. 102. — The Fall of the Horse-Chestnut Leaf.

No one knows why plants with two cotyledons should have netted-veined leaves, but many such facts as this are familiar to every botanist.

147. Simple and Compound Leaves. — The leaves so far studied are *simple leaves*, that is, leaves of which the blades are more or less entirely united into one piece. But while in the elm the margin is cut in only a little way, in some maples it is deeply cut in toward the bases of the veins. In some leaves the gaps between the adjacent portions extend all the way down to the petiole

(in palmately veined leaves) or to the midrib (in pinnately veined ones). Such divided leaves are shown in Figs. 96 and 97.

In still other leaves, known as *compound leaves*, the petiole, as shown in Fig. 102 (*palmately compound*), or the midrib, as shown in Fig. 103 (*pinnately compound*), bears what look to be separate leaves. These differ in their nature and mode of origin from the portions of the blade of a divided leaf. One result of this difference appears in the fact that some time before the whole leaf is ready to fall from the tree or other plant in autumn, the separate portions or leaflets of a compound leaf are seen to be jointed at their attachments, just as whole leaves are to the part of the stem from which they grow. In Fig. 102 the horse-chestnut leaf is shown at the time of falling, with some of the leaflets already disjointed.

FIG. 103. — Pinnately Compound Leaf of Locust, with Spines for Stipules.

FIG. 104. — Pinnately Compound Leaf of Pea. A tendril takes the place of a terminal leaflet.

That a compound leaf, in spite of the joints of the

separate leaflets, is really only one leaf is shown: (1) by the absence of buds in the axils of leaflets (see Fig. 82); (2) by the arrangement of the blades of the leaflets horizontally, without any twist in their individual leaf-stalks; (3) by the fact that their arrangement on the midrib does not follow any of the systems of leaf arrangement on the stem (Sect. 149). If each leaflet of a compound leaf should itself become compound, the result would be to produce a *twice compound* leaf. Fig. 113 shows that of an acacia. What would be the appearance of a thrice compound leaf?

148. Review Summary of Leaves.[1]

Parts of a model leaf . . . . . { 1. 2. 3.

Classes of netted-veined leaves . . . . . { 1. 2.

Classes of parallel-veined leaves . . . . . { 1. 2.

Relation of venation to number of cotyledons . . . . {

Compound leaves;—types, dependent on arrangement of leaflets . . . . . { 1. 2.

Once, twice, or three times compound . . . . . {

[1] Illustrate by sketches if possible.

CHAPTER X

LEAF ARRANGEMENT FOR EXPOSURE TO SUN AND AIR; MOVEMENTS OF LEAVES AND SHOOTS

149. Leaf Arrangement.[1] — As has been learned from the study of the leafy twigs examined, leaves are quite generally arranged so as to secure the best possible exposure to the sun and air. This, in the vertical shoots of the elm, the oak (Fig. 105), the apple, beech, and other alternate-leaved trees, is not inconsistent with their spiral arrangement of the leaves around the stem. In horizontal twigs and branches of the elm, the beech (Fig. 106), the chestnut, the linden, and many other trees and shrubs, the desired effect is secured by the arrangement of all the leaves in two flat rows, one on each side of the twig.

FIG. 105. — Leaf Arrangement of the Oak.

FIG. 106. — Leaf Arrangement of European Beech.

[1] See Kerner and Oliver's *Natural History of Plants*, Vol. I, pp. 396–424.

PLATE III. — Exposure to Sunlight, Japanese Ivy

The rows are produced, as it is easy to see on examining such a leafy twig, by a twisting about of the petioles.

FIG. 107. — Leaf Arrangement of Horse-Chestnut on Vertical Shoots (top view).

The adjustment in many opposite-leaved trees and shrubs consists in having each pair of leaves cover the spaces between the pair below it, and sometimes in the lengthening of the lower petioles so as to bring the blades of the lower leaves outside those of the upper leaves. Examination of Figs. 107 and 108 will make the matter clear.

The student should not fail to study the leafage of several trees of different kinds on the growing tree itself, and in climbers on walls (Plate III), and to notice how circumstances modify the position of the leaves. Maple leaves, for example, on the ends of the branches are arranged much

FIG. 108. — Leaf Arrangement of Horse-Chestnut on Vertical Shoots (side view).

like those of the horse-chestnut, but they are found to be arranged more nearly flatwise along the inner portions of the branches, that is, the portions nearer the tree. Figs. 109 and 110 show the remarkable difference in arrangement in different branches of the Deutzia, and equally interesting modifications may be found in alternate-leaved trees, such as the elm and the cherry.

FIG. 109. — Opposite Leaves of Deutzia[1] (from the same shrub as Fig. 110), as arranged on a Horizontal Branch.

150. Leaf-Mosaics. — In very many cases the leaves at the end of a shoot are so arranged as to form a pretty symmetrical pattern, as in the horse-chestnut (Fig. 107). When this is sufficiently regular, usually with the space between the leaves a good deal smaller than the areas of the leaves themselves, it is called a *leaf-mosaic* (Fig. 111). Many of the most interesting leaf-groups of this sort (as

[1] *Deutzia crenata.*

in the figure above mentioned) are found in the so-called root-leaves of plants. Good examples of these are the dandelion, chicory, fall dandelion, thistle, hawkweed, pyrola, plantain. How are the leaves of these plants kept from shading each other?

FIG. 110. — Opposite Leaves of Deutzia, as arranged on a Vertical Branch.

151. Much-Divided Leaves. — Not infrequently leaves are cut into slender fringe-like divisions, as in the carrot, tansy, southernwood, wormwood, yarrow, dog-fennel, cypress-vine, and many other common plants. This kind of leaf seems to be adapted to offer considerable surface to the sun without cutting off too much light from other leaves underneath. Such a leaf is in much less danger of being torn by severe winds than are broader ones with undivided margins. The same purposes are served by compound leaves with very many small leaflets, such as those of the honey-locust, mimosa acacia (Fig. 113), and other trees and shrubs of the pea family. What kind of shade is produced by a horse-chestnut or a maple tree compared with that of a honey-locust or an acacia?

FIG. 111. — Leaf-Mosaic of a Campanula.

152. Daily Movements of Leaves. — Many compound leaves have the power of changing the position of their leaflets to accommodate themselves to varying conditions of light and temperature. Some plants have the power of directing the leaves or leaflets edgewise towards the sun during the hottest parts of the day, allowing them to extend their surfaces more nearly in a horizontal direction during the cooler hours.

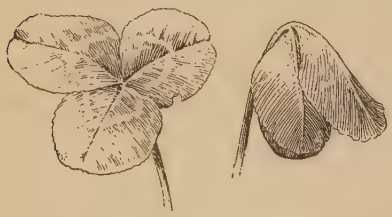


FIG. 112. — A Leaf of Red Clover.
At the left, leaf by day; at the right, the same leaf asleep at night.

The so-called "sleep" of plants has long been known, but this subject has been most carefully studied rather recently. The wood sorrel, or oxalis, the common bean, clovers, and the locust tree are some of the most familiar of the plants whose leaves assume decidedly different positions at night from those which they occupy during the day. Sometimes the leaflets rise at night, and in many instances they droop, as in the red clover (Fig. 112) and the acacia (Fig. 113). One useful purpose, at any rate, that is served by the leaf's taking the nocturnal position is protection from frost. It has been proved experimentally that when part of the leaves on a plant are prevented from assuming the folded position, while others are allowed to do so, and the plant is then exposed during a frosty night, the folded ones may escape while the others are killed. Since many plants in tropical climates fold their leaves at night, it is certain that this movement has other purposes than protection from frost, and probably there is

much yet to be learned about the meaning and importance of leaf-movements.

153. Cause of Sleep-Movements. — The student may very naturally inquire whether the change to the nocturnal position is brought about by the change from light to darkness or whether it depends rather upon the time of day. It will be interesting to try an experiment in regard to this.

EXPERIMENT XXVI

Remove a pot containing an oxalis from a sunny window to a dark closet, at about the same temperature, and note at intervals of five minutes the condition of its leaves for half an hour or more.

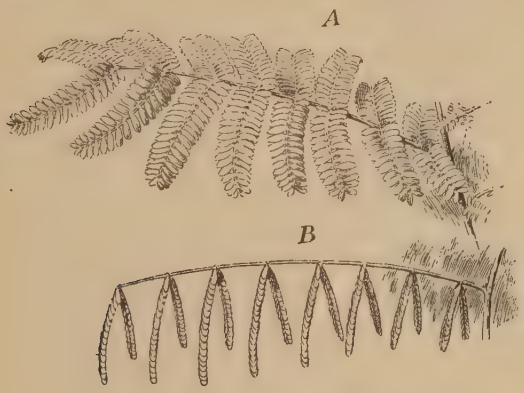


FIG. 113. — A Leaf of Acacia.
A, as seen by day; *B*, the same leaf asleep at night.

154. Structure of the Parts which cause Leaf-Motions. — In a great number of cases the daily movements of leaves are produced by special organs at the bases of the leaf-stalks. These cushion-like organs, called *pulvini* (Fig. 114), are composed mainly of parenchymatous tissue

(Sect. 106), which contains much water. It is impossible fully to explain in simple language the way in which the cells of the pulvini act, but in a general way it may be said that changes in the light to which the plant is exposed cause rather prompt changes in the amount of water in the cells in one portion or other of the pulvinus. If the cells on one side are filled fuller of water than usual, that side of the pulvinus will be expanded and make the leaf-stalk bend toward the opposite side. The promptness of these movements is no doubt in considerable measure due to the fact that in the pulvini (as in many other parts of plants) the protoplasm of adjacent cells is connected. Delicate threads of protoplasm extend through the cell-walls, making the whole tissue a living web, so that any suitable stimulus or excitant which acts on one part of the organ will soon affect the whole organ.

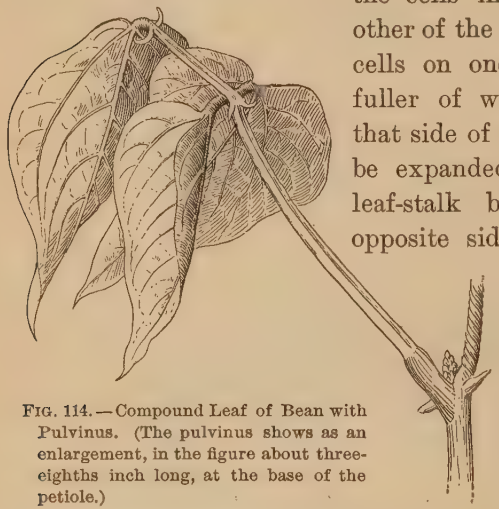


FIG. 114. — Compound Leaf of Bean with Pulvinus. (The pulvinus shows as an enlargement, in the figure about three-eighths inch long, at the base of the petiole.)

155. Vertically Placed Leaves. — Very many leaves, like those of the iris (Fig. 44), always keep their principal surfaces nearly vertical, thus receiving the morning and evening sun upon their faces, and the noonday sun (which is so intense as to injure them when received full on the

surface) upon their edges. This adjustment is most perfect in the compass-plant of the prairies of the Mississippi basin. Its leaves stand very nearly upright, many with

FIG. 115. — Leaves standing nearly Vertical in Compass-Plant (*Silphium laciniatum*). *A*, view from east or west; *B*, from north or south.

their edges just about north and south (Fig. 115), so that the rays of the midsummer sun will, during every bright

day, strike the leaf-surfaces nearly at right angles during a considerable portion of the forenoon and afternoon, while at midday only the edge of each leaf is exposed to the sun.

156. Movements of Leaves and Stems toward or away from Light (Heliotropic Movements). — The student doubtless learned from his experiments with seedling plants that their stems tend to seek light. The whole plant above ground usually bends toward the quarter from which the strongest light comes. Such movements are called *heliotropic* from two Greek words which mean turning toward the sun. How do the plants in a window behave with reference to the light?

EXPERIMENT XXVII

How do Young Shoots of English Ivy bend with Reference to Light? — Place a thrifty potted plant of English ivy before a small window, *e.g.*, an ordinary cellar window, or in a large covered box, painted dull black within and open only on the side toward a south window. After some weeks note the position of the tips of the shoots. Explain the use of their movements to the plant.

157. Positive and Negative Heliotropic Movements; how produced. — Plants may bend either toward or away from the strongest light. In the former case they are said to show *positive heliotropism*, in the latter *negative heliotropism*. In both cases the movement is produced by unequal growth, brought about by the unequal lighting of different sides of the stem. If the less strongly lighted side grows faster, what kind of heliotropism results? If the more strongly lighted side grows faster, what kind of heliotropism results? How would a plant behave if placed on a

revolving table before a window and slowly turned during the hours of daylight?

158. Review Summary of Chapter X.

- Leaf arrangement . . . { For vertical twigs . . . ; For horizontal twigs . . . }
- Movements of leaves . . { Apparatus for . . . . . ; Causes of . . . . . ; Uses of . . . . . }
- Compass-plants . . . .
- Heliotropic bending of stems { Positive . . . . . ; Negative . . . . . }

CHAPTER XI

MINUTE STRUCTURE OF LEAVES; FUNCTIONS OF LEAVES

159. Leaf of Lily. — A good kind of leaf with which to begin the study of the microscopical structure of leaves in general is that of the lily.[1]

160. Cross-Section of Lily Leaf. — The student should first examine with the microscope a cross-section of the leaf, that is, a very thin slice, taken at right angles to the upper and under surfaces and to the veins. This will show:

(*a*) The upper epidermis of the leaf, a thin, nearly transparent membrane.

(*b*) The intermediate tissues.

(*c*) The lower epidermis.

Use a power of from 100 to 200 diameters. In order to ascertain the relations of the parts, and to get their names, consult Fig. 116. Your section is by no means exactly like the figure; sketch it. Label properly all the parts shown in your sketch.

Are any differences noticeable between the upper and the lower epidermis? Between the layers of cells immediately adjacent to each?

161. Under Surface of Lily Leaf. — Examine with a power of 200 or more diameters the outer surface of a piece of epidermis from the lower side of the leaf.[2] Sketch carefully, comparing your sketch with Figs. 117 and 118, and labeling it to agree with those figures.

Examine another piece from the upper surface; sketch it.

How does the number of *stomata* in the two cases compare?

[1] Any kind of lily will answer.

[2] The epidermis may be started with a sharp knife, then peeled off with small forceps, and mounted in water for microscopical examination.

Take measurements from the last three sketches with a scale and, knowing what magnifying power was used, answer these questions[1]:

(*a*) How thick is the epidermis?

(*b*) What is the length and the breadth of the epidermal cells?

(*c*) What is the average size of the pulp-cells?

A *stoma* is a microscopic pore or slit in the epidermis. It is bounded and opened and shut by guard-cells (Fig. 118, *g*), usually two in number. These are generally

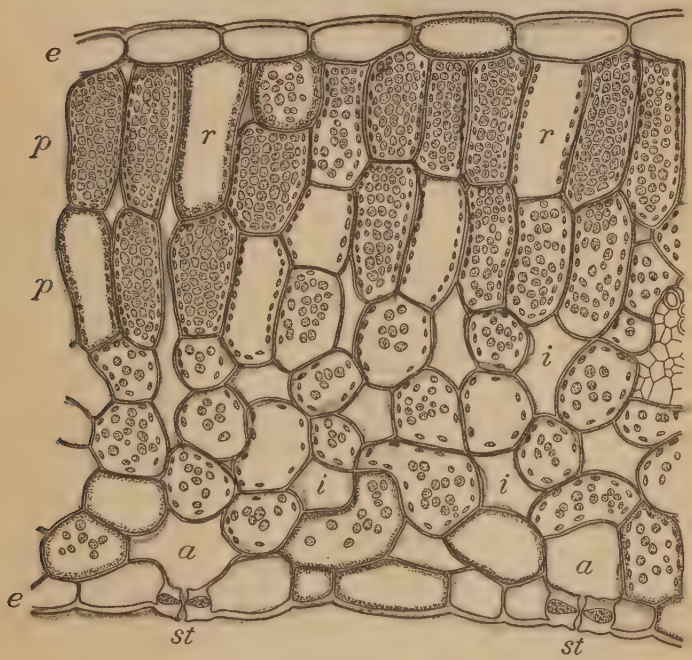


FIG. 116. — Vertical Section of the Leaf of the Beet. (Much magnified.)

e, epidermis; *p*, palisade-cells (and similar elongated cells); *r*, cells filled with red cell sap; *i*, intercellular spaces; *a*, air spaces communicating with the stomata; *st*, stomata, or breathing pores.

[1] The teacher may measure the size with the *camera lucida*.

somewhat kidney-shaped and become more or less curved as they are fuller or less full of water (see Sect. 170).

162. Calculation of Number of Stomata per Unit of Area. — In order to get a fairly exact idea of the number of stomata on a unit of leaf-surface, the most convenient plan is to make use of a photomicrograph. The total number of stomata shown should be counted, and from this number and the known area of leaf surface represented by the photomicrograph the number of stomata per square inch may easily be calculated. Another plan is to make use of an eyepiece micrometer ruled in squares. Count the average number of stomata on the epidermis itself contained in a square. The area covered by the square may be obtained by substituting a stage micrometer for the object and thus measuring the length of a side of one eyepiece division.

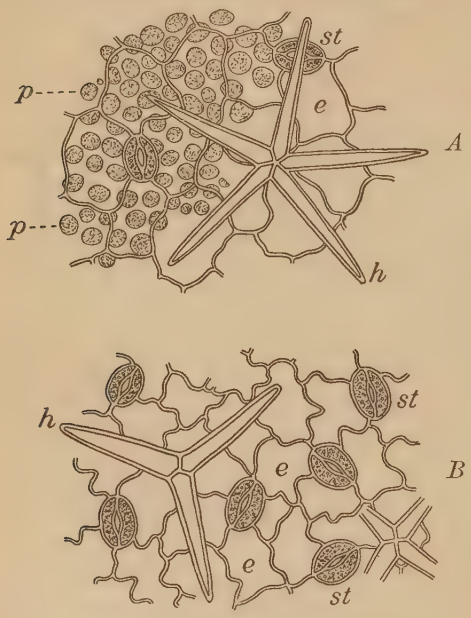


FIG. 117. — Epidermis of Leaf of Althæa. (Much magnified.)

A, from upper surface; *B*, from lower surface. *h*, star-shaped compound hairs; *st*, stomata; *p*, upper ends of palisade-cells, seen through the epidermis; *e*, cells of epidermis.

In the case of an apple tree, where the epidermis of the lower surface of the leaf contains about 24,000 stomata to the square inch, or the black walnut, with nearly 300,000 to the square inch, the total number on a tree is inconceivably large.

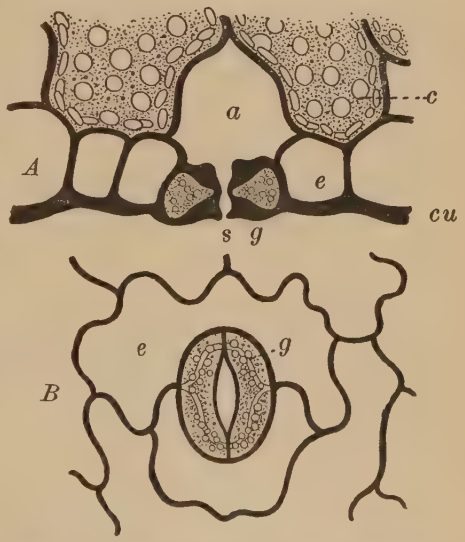


FIG. 118. — A Stoma of Thyme. (Greatly magnified.)

A, section at right angles to surface of leaf; *B*, surface view of stoma. *cu*, cuticle; *g*, guard-cells; *s*, stoma; *e*, epidermal cells; *a*, air chamber; *c*, cells of spongy parenchyma with grains of chlorophyll.

163. Uses of the Parts examined. — It will be most convenient to discuss the uses of the parts of the leaf a little later, but it will make matters simpler to state at once that the epidermis serves as a mechanical protection to the parts beneath and prevents excessive evaporation, that the palisade-cells (which it may not be easy to make out very clearly in a roughly prepared section) hold large quantities of the green coloring matter of the leaf in a position where it can receive enough but not too much sunlight, and the cells of the spongy parenchyma share the work of the palisade-cells, besides evaporating much water. The stomata admit air to the interior of the leaf (where the air spaces

serve to store and to distribute it), they allow oxygen and carbonic acid gas to escape, and by closing completely they may greatly check the loss of water from the plant.

164. Leaf of "India-Rubber Plant." [1] — Study with the microscope, as the lily leaf was studied, make the same set of sketches, note the differences in structure between the two leaves, and try to discover their meaning.

How does the epidermis of the two leaves compare?

Which has the larger stomata?

Which would better withstand great heat and long drought?

165. Chlorophyll as found in the Leaf. — Slice off a little of the epidermis from some such soft, pulpy leaf as

FIG. 119. — Section through Lower Epidermis of Leaf of India-Rubber Plant (*Ficus elastica*). (Magnified 330 diameters.)

o, opening of pit; *p*, pit leading to stoma; *s*, stoma, with two guard-cells; *w*, water-storage cells of epidermis; *a*, an air space; around and above the air spaces are cells of the spongy parenchyma.

that of the common field sorrel,[2] live-for-ever, or spinach; scrape from the exposed portion a very little of the green pulp; examine with the highest power attainable with your microscope, and sketch several cells.

[1] *Ficus elastica*, a kind of fig tree.

[2] *Rumex Acetosella.*

Notice that the green coloring matter is not uniformly distributed, but that it is collected into little particles called *chlorophyll bodies* (Fig. 120, *p*).

166. Woody Tissue in Leaves. — The veins of leaves consist of fibro-vascular bundles containing wood and vessels much like those of the stem of the plant. Indeed, these bundles in the leaf are continuous with those of the stem, and consist merely of portions of the latter, looking as if unraveled, which pass outward and upward from the stem into the leaf under the name of *leaf-traces*. These traverse the petiole often in a somewhat irregular fashion.

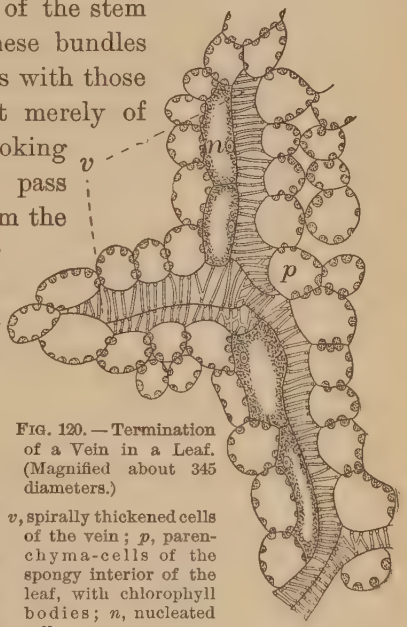


FIG. 120. — Termination of a Vein in a Leaf. (Magnified about 345 diameters.)

v, spirally thickened cells of the vein; *p*, parenchyma-cells of the spongy interior of the leaf, with chlorophyll bodies; *n*, nucleated cells.

EXPERIMENT XXVIII

Passage of Water from Stem to Leaf. — Place a freshly cut leafy shoot of some plant with large thin leaves, such as *Hydrangea Hortensia*, in eosin solution for a few minutes. As soon as the leaves show a decided reddening, pull some of them off and sketch the red stains on the scars thus made. What does this show?

167. Experimental Study of Functions of Leaves. — The most interesting and profitable way in which to find out what work leaves do for the plant is by experimenting upon them. Much that relates to the uses of leaves is

not readily shown in ordinary class-room experiments, but some things can readily be demonstrated in the experiments which follow.

EXPERIMENT XXIX

Transpiration. — Take two twigs or leafy shoots of any thin-leafed plant;[1] cover the cut end of each stem with a bit of grafting wax[2] to prevent evaporation from the cut surface. Put one shoot into a fruit jar, screw the top on, and leave in a warm room; put the other beside it, and allow both to remain some hours. Examine the relative appearance of the two, as regards wilting, at the end of the time.

Which shoot has lost most? Why? Has the one in the fruit jar lost any water? To answer this question, put the jar (without opening it) into a refrigerator; or, if the weather is cold, put it out of doors for a few minutes, and examine the appearance of the inside of the jar. What does this show?[3]

168. Uses of the Epidermis.[4] — The epidermis, by its toughness, tends to prevent mechanical injuries to the leaf, and after the filling up of a part of its outer portion with a corky substance it greatly diminishes the loss of water from the general surface. This process of becoming filled with cork substance, *suberin* (or a substance of similar properties known as *cutin*) is essential to the safety of leaves or of young stems which have to withstand heat and dryness. The corky or cutinized cell-wall is waterproof, while ordinary cellulose allows water

[1] Hydrangea, squash, melon, or cucumber is best; many other kinds will answer very well.

[2] Grafting wax may be bought of nurserymen or seedsmen.

[3] If the student is in doubt whether the jar filled with ordinary air might not behave in the same way, the question may be readily answered by putting a sealed jar of air into the refrigerator.

[4] See Kerner and Oliver's *Natural History of Plants*, Vol. I, pp. 273–362.

to soak through it with ease. Merely examining sections of the various kinds of epidermis will not give nearly as good an idea of their properties as can be obtained by studying the behavior during severe droughts of plants which have strongly cutinized surfaces and of those which have not. Fig. 121, however, may convey some notion of the difference between the two kinds of structure. The diagonally shaded parts are cutinized. Commonly the epidermal cells (and often some layers of cells beneath these) are filled with water, and thus serve as reservoirs from which the other parts of the leaf and the stem are at times supplied.

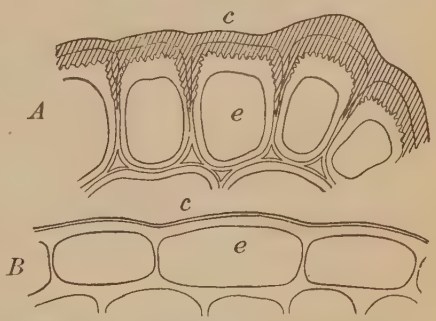


FIG. 121. — Unequal Development of Cuticle by Epidermis-Cells.

A, epidermis of Butcher's Broom (*Ruscus*); *B*, epidermis of sunflower; *c*, cuticle; *e*, epidermis-cells.

In many cases, noticeably in the cabbage, the epidermis is covered with a waxy coating, which doubtless increases the power of the leaf to retain needed moisture, and which certainly prevents rain or dew from covering the leaf-surfaces, especially the lower surfaces, so as to hinder the operation of the stomata. Many common plants, like the meadow rue and the nasturtium, possess this power to shed water to such a degree that the under surface of the leaf is hardly wet at all when immersed in water. The air-bubbles on such leaves give them a silvery appearance when held under water.

169. Hairs on Leaves. — Many kinds of leaves are more or less hairy or downy, as those of the mullein, the "mullein pink," many cinquefoils, and other common plants. In some instances this hairiness may be a protection against snails or other small leaf-eating animals, but in other cases it seems to be pretty clear that the woolliness (so often confined to the under surface) is to lessen the loss of water through the stomata. The Labrador tea is an excellent example of a plant, with a densely woolly coating on the lower surface of the leaf. The leaves, too, are partly rolled up (see Fig. 224), with the upper surface outward, so as to give the lower surface a sort of deeply grooved form, and on the lower surface all of the stomata are placed. This plant, like some others with the same characteristics, ranges far north into regions where the temperature, even during summer, often falls so low that absorption of water by the roots ceases, since it has been shown that this nearly stops a little above the freezing point of water (see Exp. XVII). Exposed to cold, dry winds, the plant would then often be killed by complete drying if it were not for the protection afforded by the woolly, channeled under surfaces of the leaves.[1]

170. Operation of the Stomata. — When the stomata are closed little water can escape from ordinary leaves, and from those with a thick, leathery epidermis (Fig. 119) hardly any moisture is then given off. Open stomata serve to admit air to the interior of the leaf and to allow carbon dioxide and moisture in the form of vapor to pass out of it. Excretion of water-vapor is called *transpiration*. The opening is

[1] This adaptation is sufficiently interesting for class study.

PLATE IV. — A Cypress Swamp

caused by each of the guard-cells bending into a more kidney-like form than usual, and the closing by a straightening out of the guard-cells. The under side of the leaf, free from palisade-cells, abounding in intercellular spaces, and pretty well protected from becoming covered with rain or dew, is especially adapted for the working of the stomata, and accordingly we usually find them in much greater numbers on the lower surface. On the other hand, the little flowerless plants known as liverworts, which lie prostrate on the ground, have their stomata on the upper surface, and so do the leaves of pond lilies, which lie flat on the water. In those leaves which stand with their edges nearly vertical, the stomata are distributed somewhat equally on both surfaces. Stomata occur in the epidermis of young stems, being replaced later by the lenticels. Those plants which, like the cacti, have no ordinary leaves, transpire through the stomata scattered over their general surfaces.

The health of the plant depends largely on the proper working condition of the stomata, and one reason why plants in cities often fail to thrive is that the stomata become choked with dust and soot. In some plants, as the oleander, provision is made for the exclusion of dust by a fringe of hairs about the opening of each stoma. If the stomata were to become filled with water, their activity would cease until they were freed from it; hence many plants have their leaves, especially the under surfaces, protected by a coating of wax which sheds water.

171. Measurement of Transpiration. — We have already proved that water is lost by the leaves, but it is worth while to perform a careful experiment to reduce our

knowledge to an exact form, to learn how much water a given plant transpires under certain conditions. It is also desirable to find out whether different kinds of plants transpire alike, and what changes in the temperature, the dampness of the air, the brightness of the light, to which a plant is exposed, have to do with its transpiration. Another experiment will show whether both sides of a leaf transpire alike.

EXPERIMENT XXX

Amount of Water lost by Transpiration. — Procure a thrifty hydrangea[1] and a small "india-rubber plant,"[2] each growing in a small flower-pot, and with the number of square inches of leaf-surface in the two plants not too widely different. Calculate the area of the leaf-surface for each plant, by dividing the surface of a piece of tracing cloth into a series of squares one-half inch on a side, holding an average leaf of each plant against this and counting the number of squares and parts of squares covered by the leaf. Or weigh a square inch of tinfoil on a very delicate balance, cut out a piece of the same kind of tinfoil of the size of an average leaf, weigh this and calculate the leaf-area from the two weights. This area, multiplied by the number of leaves for each plant, will give approximately the total evaporating surface for each.

FIG. 122. — A Hydrangea potted in a Battery Jar for Exp. XXX.

Transfer each plant to a glass battery jar of suitable size. Cover

[1] The common species of the greenhouses, *Hydrangea Hortensia*.
[2] This is really a fig, *Ficus elastica*.

the jar with a piece of sheet lead, slit to admit the stem of the plant, invert the jar and seal the lead to the glass with a hot mixture of beeswax and rosin. Seal up the slit and the opening about the stem with grafting wax. A thistle-tube, such as is used by chemists, is also to be inserted, as shown in Fig. 122.[1] The mouth of this may be kept corked when the tube is not in use for watering.

Water each plant moderately and weigh the plants separately on a balance that is sensitive to one-fifth gram. Record the weights, allow the plants to stand in a sunny, warm room for twenty-four hours and reweigh.

Add to each plant just the amount of water which is lost,[2] and continue the experiment in the same manner for several days so as to ascertain, if possible, the effect upon transpiration of varying amounts of water in the atmosphere.

Calculate the average loss per 100 square inches of leaf-surface for each plant throughout the whole course of the experiment. Divide the greater loss by the lesser to find their ratio. Find the ratio of each plant's greatest loss per day to its least loss per day, and by comparing these ratios decide which transpires more regularly.

Try the effect of supplying very little water to each, so that the hydrangea will begin to droop, and see whether this changes the relative amount of transpiration for the two plants. Vary the conditions of the experiment for a day or two as regards temperature, and again for a day or two as regards light, and note the effect upon the amount of transpiration.

The structure of the fig (India-rubber plant) leaf has already been studied. That of the hydrangea is looser in texture and more like the leaf of the lily or the beet (Fig. 116).

What light does the structure throw on the results of the preceding experiment?

[1] It will be much more convenient to tie the hydrangea if one has been chosen that has but a single main stem. Instead of the hydrangea, the common cineraria, *Senecio cruentus*, does very well.

[2] The addition of known amounts of water may be made most conveniently by measuring it in a cylindrical graduate.

EXPERIMENT XXXI

Through which Side of a Leaf of the India-Rubber Plant does Transpiration occur? — The student may already have found (Sect. 164) that there are no stomata on the upper surface of the fig leaf which he studied. That fact makes this leaf an excellent one by means of which to study the relation of stomata to transpiration.

Take two large, sound rubber-plant leaves, cut off pretty close to the stem of the plant. Slip over the cut end of the petiole of each leaf a piece of small rubber tubing, wire this on, leaving about half of it free, then double the free end over and wire tightly, so as to make the covering moisture-proof. Warm some vaseline or grafting wax until it is almost liquid, and spread a thin layer of it smoothly over the upper surface of one leaf and the lower surface of the other. Hang both up in a sunny place in the laboratory and watch them for a month or more.

What difference in the appearance of the two leaves becomes evident? What does the experiment prove?

172. Endurance of Drought by Plants. — Plants in a wild state have to live under extremely different conditions as regards water supply (see Chapter XXIV). Observation of growing plants during a long drought will quickly show how differently the various species of a region bear the hardships due to a scanty supply of moisture. It is still easier, however, to subject some plants to an artificial drought and watch their condition.

EXPERIMENT XXXII

Resistance to Drought. — Procure at least one plant from each of these groups:

Group I. Melon-cactus (*Echinocactus* or *Mamillaria*), prickly pear cactus.

Group II. Aloe, *Cotyledon* (often called *Echeveria*), houseleek.

Group III. Live-for-ever (*Sedum Telephium*), *Bryophyllum*, English ivy, "ivy-leafed geranium," (*Pelargonium peltatum*), or any of the fleshy-leafed begonias.

Group IV. Hydrangea (*H. Hortensia*), squash or cucumber, sunflower.

The plants should be growing in pots and well rooted. Water them well and then put them all in a warm, sunny place. Note the appearance of all the plants at the end of twenty-four hours. If any are wilting badly, water them. Keep on with the experiment, in no case watering any plant or set of plants until it has wilted a good deal. Record the observations in such a way as to show just how long a time it took each plant to begin to wilt from the time when the experiment began. If any hold out more than a month, they may afterwards be examined at intervals of a week, to save the time required for daily observations. If possible, account by the structure of the plants for some of the differences observed. Try to learn the native country of each plant used and the soil or exposure natural to it.

173. Course traversed by Water through the Leaf. — The same plan that was adopted to trace the course of water in the stem (Exp. XXI) may be followed to discover its path through the leaf.

EXPERIMENT XXXIII

Rise of Sap in Leaves. — Put the freshly cut ends of the petioles of several thin leaves of different kinds into small glasses, each containing eosin solution to the depth of one-quarter inch or more. Allow them to stand for half an hour, and examine them by holding up to the light and looking through them to see into what parts the eosin solution has risen. Allow some of the leaves to remain as much as twelve hours, and examine them again. The red-stained portions of the leaf mark the lines along which, under natural conditions, sap rises into it. Cut across (near the petiole or midrib ends) all the principal veins of some kind of large, thin leaf. Then cut off the petiole and at once stand the cut end, to which the blade

is attached, in eosin solution. Repeat with another leaf and stand in water. What do the results teach?

174. Total Amount of Transpiration. — In order to prevent wilting, the rise of sap during the life of the leaf must have kept pace with the evaporation from its surface. The total amount of water that travels through the roots, stems, and leaves of most seed-plants during their lifetime is large, relative to the weight of the plant itself. During 173 days of growth a corn-plant has been found to give off nearly 31 pounds of water. During 140 days of growth a sunflower-plant gave off about 145 pounds. A grass-plant has been found to give off its own weight of water every twenty-four hours in hot, dry summer weather. This would make about $6\frac{1}{2}$ tons per acre every twenty-four hours for an ordinary grass-field, or rather over 2200 pounds of water from a field 50×150 feet, that is, not larger than a good-sized city lot. Calculations based on observations made by the Austrian forest experiment stations showed that a birch tree with 200,000 leaves, standing in open ground, transpired on hot summer days from 700 to 900 pounds, while at other times the amount of transpiration was probably not more than 18 to 20 pounds.[1]

These large amounts of water are absorbed, carried through the tissues of the plant, and then given off by the leaves because the plant-food contained in the soil-water is in a condition so diluted that great quantities of water must be taken in order to secure enough of the mineral and other substances which the plant demands from the soil. Active transpiration may also have other causes.

[1] See B. E. Fernow's discussion in Report of Division of Forestry of U. S. Department of Agriculture, 1889.

Meadow hay contains about two per cent of potash, or 2000 parts in 100,000, while the soil-water of a good soil does not contain more than one-half part in 100,000 parts. It would therefore take 4000 tons of such water to furnish the potash for one ton of hay. The water which the root-hairs take up must, however, contain far more potash than is assumed in the calculation above given, so that the amount of water actually used in the growth of a ton of hay cannot be much more than 260 tons.[1]

175. Accumulation of Mineral Matter in the Leaf. — Just as a deposit of salt is found in the bottom of a seaside pool of salt water which has been dried up by the sun, so old leaves are found to be loaded with mineral matter, left behind as the sap drawn up from the roots is evaporated through the stomata. A bonfire of leaves makes a surprisingly large heap of ashes. An abundant constituent of the ashes of burnt leaves is silica, a substance chemically the same as sand. This the plant is forced to absorb along with the potash, compounds of phosphorus, and other useful substances contained in the soil-water; but since the silica is of hardly any value to most plants, it often accumulates in the leaf as so much refuse. Lime is much more useful to the plant than silica, but a far larger quantity of it is absorbed than is needed; hence it, too, accumulates in the leaf.

176. Nutrition, Metabolism.[2] — The manufacture of the more complex plant-foods, starch, sugar, and so on, from

[1] See the article, "Water as a Factor in the Growth of Plants," by B. T. Galloway and Albert F. Woods, *Year-Book of U. S. Department of Agriculture, 1894.*

[2] See Kerner and Oliver's *Natural History of Plants*, Vol. I, pp. 371–483. Also Pfeffer's *Physiology of Plants*, translated by Ewart, Chapter VIII.

the raw materials which are afforded by the earth and air and all the steps of the processes by which these foods are used in the life and growth of the plant are together known as its *nutrition*. When we think more of the chemical side of nutrition than of its relation to plant-life, we call any of the changes or all of them *metabolism*, which means simply chemical transformation in living tissues. There are two main classes of metabolism — the constructive kind, which embraces those changes which build up more complicated substances out of simpler ones (Sect. 179), and the destructive kind, the reverse of the former (Sect. 184). A good many references to cases of plant metabolism have been made in earlier chapters, but the subject comes up in more detail in connection with the study of the work of leaves than anywhere else, because the feeding which the ordinary seed-plant does is very largely done in and by its leaves.

177. Details of the Work of the Leaf. — A leaf has four functions to perform: (1) Starch-making; (2) assimilation;[1] (3) excretion of water; (4) respiration.

178. Absorption of Carbon Dioxide and Removal of its Carbon. — Carbon dioxide is a constant ingredient of the atmosphere, usually occurring in the proportion of about three parts in every 10,000 of air or one thirty-third of one per cent. It is a colorless gas, a compound of two simple substances or elements, carbon and oxygen, the former familiar to us in the forms of charcoal and graphite, the latter occurring as the active constituent of air.

[1] In many works on Botany (1) and (2) are both compounded under the term *assimilation*. Many botanists (most of the American ones) apply the name *photosynthesis* or *photosyntax* to the starch-making process, but these names are not wholly satisfactory, and perhaps it is as well (as suggested by Professor Atkinson) to name the process from its result.

Carbon dioxide is produced in immense quantities by the decay of vegetable and animal matter, by the respiration of animals, and by all fires in which wood, coal, gas, or petroleum is burned.

Green leaves and the green parts of plants, when they contain a suitable amount of potassium salts, have the power of removing carbon dioxide from the air (or in the case of some aquatic plants from water in which it is dissolved), retaining its carbon and setting free part or all of the oxygen. This process is an important part of the work done by the plant in making over raw materials into food from which it forms its own substance.

EXPERIMENT XXXIV

Oxygen-Making in Sunlight. — Place a green aquatic plant in a glass jar full of water, at a temperature of about 70° Fahrenheit in front of a sunny window.[1] On the surfaces of the plants watch for minute silvery looking bubbles. These may be partly air, but some are oxygen. Remove to a dark closet for a few minutes and examine by lamplight, to see whether the rise of bubbles still continues.

This gas may be shown to be oxygen by collecting some of it in a small inverted test-tube filled with water and thrusting the glowing coal of a match just blown out into the gas. It is not, however, very easy to do this satisfactorily before the class.

Repeat the experiment, using water which has been well boiled and then quickly cooled. Boiling removes all the dissolved gases from water, and they are not re-dissolved in any considerable quantity for many hours.

[1] *Elodea*, *Myriophyllum*, *Chrysosplenium*, *Potamogeton*, *Fontinalis*, any of the green aquatic flowering plants, or even the common confervaceous plants, known as *pond-scum* or "frog-spit," will do for this experiment.

Ordinary air, containing a known per cent of carbon dioxide, if passed very slowly over the foliage of a plant covered with a bell-glass and placed in full sunlight, will, if tested chemically, on coming out of the bell-glass be found to have lost a little of its carbon dioxide. The pot in which the plant grows must be covered with a lid, closely sealed on, to prevent air charged with carbon dioxide (as the air of the soil is apt to be) from rising into the bell-glass.

179. Disposition made of the Absorbed Carbon Dioxide. — It would lead the student too far into the chemistry of botany to ask him to follow out in detail the changes by which carbon dioxide lets go part at least of its oxygen and gives its remaining portions, namely, the carbon, and perhaps part of its oxygen, to build up the substance of the plant. Starch is composed of three elements: hydrogen (a colorless, inflammable gas, the lightest of known substances), carbon, and oxygen. Water is composed largely of hydrogen, and, therefore, carbon dioxide and water contain all the elements necessary for making starch. The chemist cannot put these elements together to form starch, but the plant can do it, and at suitable temperatures starch-making goes on constantly in the green parts of plants when exposed to sunlight and supplied with water and carbon dioxide.[1] The seat of the manufacture is in the chlorophyll bodies, and protoplasm is without doubt the manufacturer, but the process is not understood by chemists or botanists. No carbon dioxide can be taken up and used by plants growing in the dark, nor in an atmosphere containing only carbon dioxide, even in the light.

[1] Very likely the plant makes sugar first of all and then rapidly changes this into starch. However that may be, the first kind of food made in the leaf and retained long enough to be found there by ordinary tests is starch. See Pfeffer's *Physiology of Plants*, translated by Ewart, Vol. I, pp. 317, 318.

PLATE V.—A Saprophyte, Indian Pipe

A very good comparison of the leaf to a mill has been made as follows[1]:

The mill:	Palisade-cells and underlying cells of the leaf.
Raw material used:	Carbon dioxide, water.
Milling apparatus:	Chlorophyll grains.
Energy by which the mill is run:	Sunlight.
Manufactured product:	Starch.
Waste product:	Oxygen.

180. Plants Destitute of Chlorophyll not Starch-Makers. — Aside from the fact that newly formed starch grains are first found in the chlorophyll bodies of the leaf and the green layer of the bark, one of the best evidences of the intimate relation of chlorophyll to starch-making is derived from the fact that plants which contain no chlorophyll cannot make starch from water and carbon dioxide. Parasites, like the dodder, which are nearly destitute of green coloring matter, cannot do this; neither can *saprophytes* or plants which live on decaying or fermenting organic matter, animal or vegetable. Most saprophytes, like the moulds, toadstools, and yeast, are flowerless plants of low organization, but there are a few (such as the Indian pipe (Plate V), which flourishes on rotten wood or among decaying leaves) that bear flowers and seeds.

181. Detection of Starch in Leaves. — Starch may be found in abundance by microscopical examination of the green parts of growing leaves, or its presence may be shown by testing the whole leaf with iodine solution.

[1] By Professor George L. Goodale.

EXPERIMENT XXXV

Occurrence of Starch in Nasturtium Leaves. — Toward the close of a very sunny day collect some bean leaves or leaves of nasturtium (*Tropæolum*). Boil these in water for a few minutes, to kill the protoplasmic contents of the cells and to soften and swell the starch grains.[1]

Soak the leaves, after boiling, in strong alcohol for a day or two, to dissolve out the chlorophyll, which would otherwise make it difficult to see the blue color of the starch test, if any were obtained. Rinse out the alcohol with plenty of water and then place the leaves for ten or fifteen minutes in a solution of iodine, rinse off with water and note what portions of the leaf, if any, show the presence of starch.

FIG. 123. — Leaf of Tropæolum partly covered with Disks of Cork and exposed to Sunlight.

EXPERIMENT XXXVI

Consumption of Starch in Nasturtium (*Tropæolum*) Leaves. — Select some healthy leaves of Tropæolum on a plant growing vigorously indoors or, still better, in the open air. Shut off the sunlight from parts of the selected leaves (which are to be left on the plant and as little injured as may be) by pinning circular disks of cork on opposite sides of the leaf, as shown in Fig. 123. On the afternoon of the next day remove these leaves from the plant and treat as described in the preceding experiment, taking especial pains to get rid of all the chlorophyll by changing the alcohol as many times as may be necessary. What does this experiment show in regard to the consumption of starch in the leaf? What has caused its disappearance?

182. Rate at which Starch is manufactured. — The amount of starch made in a day by any given area of

[1] The leaves, collected as above described, may, after boiling, be kept in alcohol for winter use. They also make excellent material for the microscopical study of starch in the leaf.

foliage must depend on the kind of leaves, the temperature of the air, the intensity of the sunlight, and some other circumstances. Sunflower leaves and pumpkin or squash leaves have been found to manufacture starch at about the same rate. In a summer day fifteen hours long they can make nearly three-quarters of an ounce of starch for each square yard of leaf-surface. A full-grown squash leaf has an area of about one and one-eighth square feet, and a plant may bear as many as 100 leaves. What would be the daily starch-making capacity of such a plant?[1]

183. Assimilation. — From the starch in the leaf, grape-sugar or malt-sugar is readily formed, and some of this in turn is apparently combined on the spot with nitrogen, sulphur, and phosphorus. These elements are derived from nitrates, sulphates, and phosphates, taken up in a dissolved condition by the roots of the plant and transported to the leaves. The details of the process are not understood, but the result of the combination of the sugars or similar substances with suitable (very minute) proportions of nitrogen, sulphur, and phosphorus is to form complex nitrogen compounds. These are not precisely of the same composition as the living protoplasm of plant-cells or as the reserve proteids stored in seeds (Sects. 14, 17), stems (Sect. 127), and other parts of plants, but are readily changed into protoplasm or proteid foods as necessity may demand.

Assimilation is by no means confined to leaves ; indeed, most of it, as above suggested, must take place in other parts of the plant. For instance, the manufacture of the immense amounts of cellulose, of cork, and of the com-

[1] See Pfeffer's *Physiology of Plants*, translated by Ewart, Vol. I, p. 324.

pound (*lignin*) characteristic of wood-fiber, that go to make up the main bulk of a large tree must be carried on in the roots, trunk, and branches of the tree.

184. Digestive Metabolism. — Plant-food in order to be carried to the parts where it is needed must be dissolved, and this dissolving often involves a chemical change and is somewhat similar to digestion as it occurs in animals. The newly made starch in the leaf must be changed to a sugar or other substance soluble in water before it can be carried to the parts of the plant where it is to be stored or to rapidly growing parts where it is to be used for building material. On the other hand, starch, oil, and such insoluble proteids as are deposited in the outer portion of the kernel of wheat and other grains are extremely well adapted to serve as stored food, but on account of their insoluble nature are quite unfit to circulate through the tissues of the plant. The various kinds of sugar are not well adapted for storage, since they ferment easily in the presence of warmth and moisture if yeast-cells or suitable kinds of bacteria are present.

Two important differences between starch-making in the green parts of plants and the non-constructive or the destructive type of metabolism should be carefully noticed. These latter kinds of metabolism go on in the dark as well as in the light and do not add to the total weight of the plant.

185. Excretion of Water and Respiration. — Enough has been said in Sect. 174 about the former of these processes. *Respiration*, or taking in and consuming oxygen and giving off carbon dioxide, is an operation which goes on as constantly in plants as in animals, and is necessary to

their life. For, like animals, plants get the energy with which they do the work of assimilation, growth, reproduction, and performing their movements from the oxidation of such combustible substances as oil, starch, and sugar.[1]

The amount of oxygen absorbed and of carbon dioxide given off is, however, so trifling compared with the amount of each gas passing in the opposite direction, while starch-making is going on in sunlight, that under such circumstances it is difficult to observe the occurrence of respiration. In ordinary leafy plants the leaves (through their stomata) are the principal organs for absorption of air, but much air passes into the plant through the lenticels of the bark.

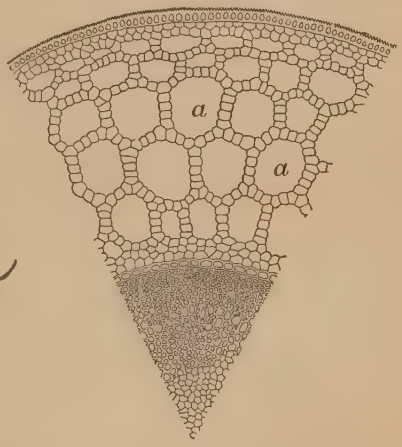


FIG. 124. — Cross-Section of Stem of Marestail (*Hippuris*) with Air-Passages, *a*.

In partly submerged aquatics especial provisions are found for carrying the air absorbed by the leaves down to the submerged parts. This is accomplished in pond lilies by ventilating tubes which traverse the leaf-stalks lengthwise. In many cases such channels run up and down the stem (Fig. 124).

[1] The necessity of an air supply about the roots of the plant may be shown by filling the pot or jar in which the hydrangea was grown for the transpiration experiment perfectly full of water and noting the subsequent appearance of the plant at periods twelve to twenty-four hours apart.

186. Tabular Summary of Metabolic and Other Processes.[1]

Name of process	By what apparatus or agency carried on	By what kind of energy carried on	Substances acted on	Useful products	Waste products
Starch-making	Chlorophyll bodies of leaves and green stems	Sunlight and heat, energy of protoplasm	Carbon dioxide and water	Sugar and starch	Oxygen, passed out of stomata
Assimilation (Tissue Building)	Living protoplasm in leaves and elsewhere		Sugar and compounds containing nitrogen, sulphur, and phosphorus	Proteids for storage. Protoplasm for live, active cells	
Digestion	Various ferments or enzymes		Starch, cellulose, stored proteids	Sugars, proteids in soluble forms	
Excretion of water (Transpiration)	Cells of pulpy interior of leaf around air spaces	Heat, vaporizing water	Soil-water brought up from roots	Potassium salts and other useful inorganic compounds stored	Water vapor, passed out of stomata. Lime salts, silica, etc., deposited in the leaf
Respiration	All live cells of interior of root, stem or leaf when supplied with air	Chemical attraction between oxygen and combustible substances	Sugars and oils	Energy (*i.e.*, power to do work)	Carbon dioxide, water

[1] It is to be understood that this table only includes a small portion of the whole series of metabolic processes which go on in green plants, but it embraces some of the most important ones. Excretion of water is not a metabolic process, but is inserted here for the purpose of making the showing of the work of the leaf as complete as possible.

187. The Fall of the Leaf. — In the tropics trees retain most of their leaves the year round; a leaf occasionally falls, but no considerable portion of them drops at any one season.[1] The same statement holds true in regard to our cone-bearing evergreen trees, such as pines, spruces, and the like. But the impossibility of absorbing soil-water when the ground is at or near the freezing temperature (Exp. XVII) would cause the death, by drying up, of trees with broad leaf-surfaces in a northern winter. And in countries where there is much snowfall, most broad-leafed trees could not escape injury to their branches from overloading with snow, except by encountering winter storms in as close-reefed a condition as possible. For such reasons our common shrubs and forest trees (except the cone-bearing, narrow-leafed ones already mentioned) are mostly *deciduous*, that is they shed their leaves at the approach of winter.

The fall of the leaf is preceded by important changes in the contents of its cells.

EXPERIMENT XXXVII

Does the Leaf vary in its Starch Contents at Different Seasons?

Collect in early summer some leaves of several kinds of trees and shrubs and preserve them in alcohol. Collect others as they are beginning to drop from the trees in autumn and preserve them in the same way. Test some of each lot for starch as described in Sect. 181.

What does the result indicate?

Much of the sugary and protoplasmic contents of the leaf disappears before it falls. These valuable materials

[1] Except where there is a severe dry season.

have been absorbed by the branches and roots, to be used again the following spring.

The separation of the leaf from the twig is accomplished by the formation of a layer of cork cells across the base of the petiole in such a way that the latter finally breaks off across the surface of the layer. A waterproof scar is thus already formed before the removal of the leaf, and there is no waste of sap dripping from the wound where the leaf-stalk has been removed, and no chance for moulds to attack the bark or wood and cause it to decay. In compound leaves each leaflet may become separated from the petiole, as is notably the case with the horse-chestnut leaf (Fig. 102). In woody monocotyledons, such as palms, the leaf-stalks do not commonly break squarely off at the base, but wither and leave projecting stumps on the stem (Plate VI).

The brilliant coloration, yellow, scarlet, deep red, and purple, of autumn leaves is popularly but wrongly supposed to be due to the action of frost. It depends merely on the changes in the chlorophyll grains and the liquid cell-contents that accompany the withdrawal of the proteid material from the tissues of the leaf. The chlorophyll turns into a yellow insoluble substance after the valuable materials which accompany it have been taken away, and the cell sap at the same time may turn red. Frost perhaps hastens the break-up of the chlorophyll, but individual trees often show bright colors long before the first frost, and in very warm autumns most of the changes in the foliage may come about before there has been any frost.

188. Tabular Review of Experiments.

[Continue the table from Sect. 128.]

PLATE VI.—Fan Palms

189. Review Summary of Minute Structure of Leaves.[1]

- General structure, distribution of parenchyma, and prosenchyma
- Layers of tissue seen on a cross-section
- Structure of epidermis
- Structure of stomata
- Distribution of stomata
- Structure and distribution of chlorophyll bodies

190. Review Summary of Functions of Leaves.

- Principal uses of
  - fibro-vascular bundles
  - epidermis
  - stomata
  - air spaces
  - palisade-cells
  - spongy parenchyma
  - waxy coating
  - hairs
- Substances received by the leaf
  - from the air
  - from the soil
- Substances manufactured by the leaf
- Substances given off by the leaf
  - into the air
  - into the stem
- Mineral substances accumulated in the leaf
- Statistics in regard to transpiration
- Statistics in regard to starch-making

[1] Illustrate with sketches and diagrams.

CHAPTER XII

PROTOPLASM AND ITS PROPERTIES

191. The Cell in its Simplest Form. — Sufficient has been said in the preceding chapters, and enough tissues have been microscopically studied, to make it pretty clear what vegetable cells, as they occur in flowering plants, are like. In Chapter XI, leaf-cells have been taken for granted and their work described in some detail. Before going further, it is worth while to consider the structure of an individual cell, and to see of what kinds of activity it is capable.

In studying the minute anatomy of bark, wood, pith, and other tissues the attention is often directed to the *cell-wall* without much regard to the nature of the *cell-contents*. Yet the cell-wall is not the cell, any more than the lobster shell or the crayfish shell is the lobster or the crayfish. *The contained protoplasm with its nucleus is the cell.*[1] The cell reduced to its lowest terms need not have a cell-wall, but may consist simply of a mass of protoplasm, usually containing a portion of denser consistency than the main bulk, known as the *nucleus*.

Such cells, without a cell-wall, are not common in the vegetable world, but are frequently encountered among animals.

192. The Slime Moulds.[2] — One of the best examples of masses of naked protoplasm leading an individual existence

[1] See Kerner and Oliver's *Natural History of Plants*, Vol. I, pp. 21–51.

[2] Strasburger, Noll, Schenk, and Karsten's *Text-Book of Botany*, pp. 54, 55 and 340–342.

is found in the slime moulds, which live upon rotten tan bark, decaying wood, and so on. These curious organisms have so many of the characteristics both of animals and of plants that they have been described in zoölogies under the former title and in botanies under the latter one. Perhaps it would not really be so absurd a statement as it might seem, to say that every slime mould leads the life of an animal during one period of its existence and of a plant at another period. At any rate, whatever their true nature, these little masses of unenclosed protoplasm illustrate admirably some of the most important properties of protoplasm. Slime moulds spring from minute bodies called *spores* (Fig. 125, *a*) which differ from the seeds of seed-plants not only in their microscopic size but still more in their lack of an embryo. The spores of slime moulds are capable, when kept dry, of preserving for many years their power of germination, but in the presence of moisture and warmth they will germinate as soon as they are scattered. During the process of germination the spore swells, as shown at *b*, and then bursts, discharging its protoplasmic contents, as seen at *c* and *d*. This in a few minutes lengthens out and produces at one end a hair-like *cilium*, as shown at *e*, *f*, *g*. These ciliated bodies are called *swarmspores*, from their power of swimming freely about by the vibrating motion of the cilia. Every swarmspore has at its ciliated end a *nucleus*, and at the other end a bubble-like object which gradually expands, quickly disappears, and then again expands. This *contractile vacuole* is commonly met with in animalcules, and increases the likeness between the slime moulds and many microscopic animals. The next change of the swarmspores is into an

Amœba form (so called from one of the most interesting and simplest of animals, the *Amœba*, found on the surface of

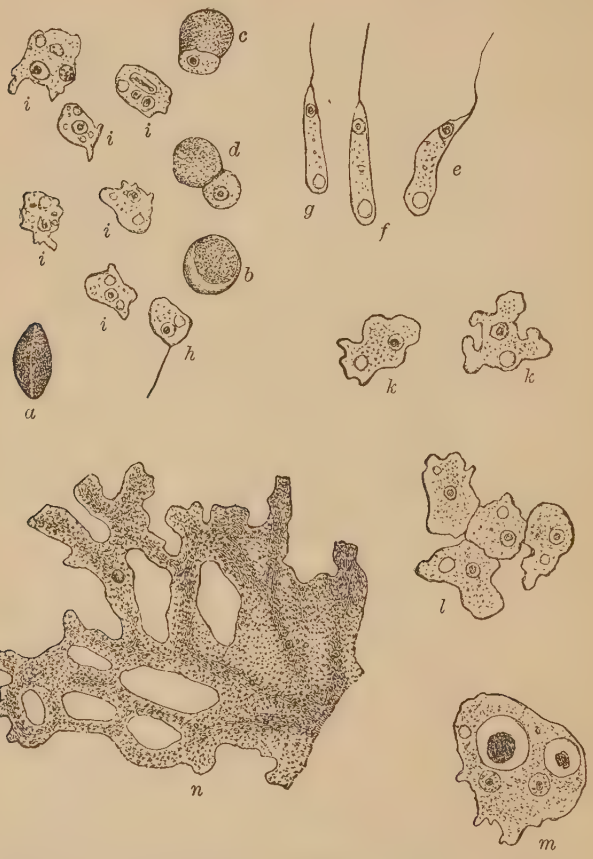


FIG. 125. — A Slime Mould. (*a–m*, inclusive, × 540 times, *n* × 90 times.)

mud and the leaves of water plants). In this condition, as shown at *h*, *i*, *k*, the spores creep about over the surface of the decaying vegetable material on which the

slime moulds live. Their movement is caused by a thrusting out of the semi-liquid protoplasm on one side of the mass, and a withdrawal of its substance from the other side. At length many amœba-shaped bodies unite, as at *l*, to form a larger mass, *m*, which finally increases to the protoplasmic network shown at *n*. This eventually collects into a roundish or egg-shaped firm body, inside of which a new crop of spores is produced. It is not easy to trace the manner in which the nourishment of these simple plants is taken. Probably they absorb it from the decaying matter upon which they live during their amœba-like period, and after they have formed the larger masses, *n*.

193. Characteristics of Living Protoplasm.[1] — The behavior of the slime moulds during their growth and transformations, as just outlined, affords a fair idea of several of the remarkable powers which belong to living protoplasm, which have been summed up as follows:

(1) The power to take up new material into its own substance (*selective absorption*). This is not merely a process of soaking up liquids, such as occurs when dry earth or a sponge is moistened. The protoplasmic lining of a root-hair, for example, selects from the soil-water some substances and rejects others (Sect. 65).

(2) The ability to change certain substances into others of different chemical composition (*metabolism*, Sect. 176). Carbon dioxide and water, losing some oxygen in the process, are combined into starch; starch is changed into various kinds of sugar and these back into starch again; starch becomes converted into vegetable acids, into cellulose, or into oil; or the elements of starch are combined

[1] See Huxley's *Essays*, Vol. I, essay on "The Physical Basis of Life."

with nitrogen to make various proteid compounds, either for immediate use or for reserve food. Many other complicated transformations occur.

(3) The power to cast off waste or used-up material (*excretion*). Getting rid of surplus water (Sect. 174) and of oxygen (Sect. 178) constitutes a very large part of the excretory work of plants.

(4) The capacity for growth and the production of offspring (*reproduction*). These are especially characteristic of living protoplasm. It is true that non-living objects may grow in a certain sense, as an icicle or a crystal of salt or of alum in a solution of its own material does. But growth by the process of taking suitable particles into the interior of the growing substance and arranging them into an orderly structure (Fig. 126) is possible only in the case of live protoplasm.

(5) The possession of the power of originating movements not wholly and directly caused by any external impulse (*automatic movements*). Such, for instance, are the lashing movements of the cilia of the swarmspores of slime moulds, or the slow pendulum movements of *Oscillatoria* (Sect. 269), or the slow vibrating movements of the stipules of the "telegraph plant" (*Desmodium*), not uncommon in greenhouses.

(6) The power of shrinking or closing up (*contractility*). This is illustrated by the action of the contractile vacuole of the slime moulds and of many animalcules and by all the muscular movements of animals.

(7) Sensitiveness when touched by any solid object or otherwise disturbed, for instance, by a change of light or of temperature.

194. Nature and Occurrence of Irritability in Plants.[1] — Mention has already been made of the fact that certain parts of plants respond to suitable *stimuli* that is exciting

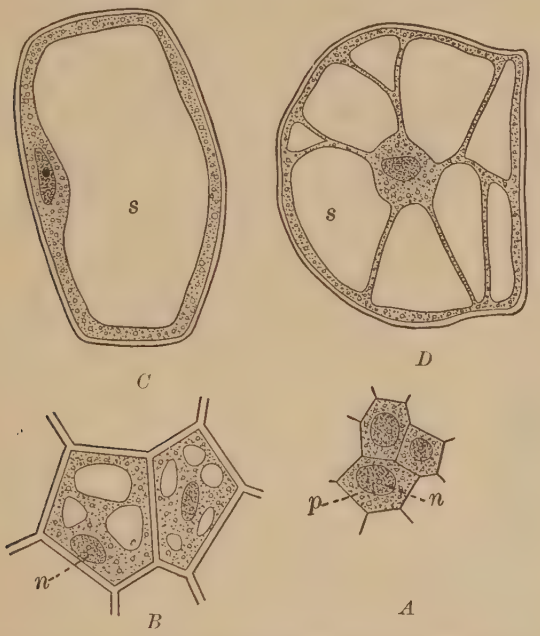


FIG. 126. — Protoplasm in Ovule and Fruit of Snowberry (*Symphoricarpus racemosus*).

A, cells from ovule, × 340; *B*, cells from an ovule further developed, × 340; *C*, *D*, cells from pulp of fruit, × 110; *n*, nucleus; *p*, protoplasm; *s*, cell-sap.

In the young and rapidly growing cells, *A* and *B*, the cell-sap is not present, or present only in small quantities, while in the older cells, *C* and *D*, it occupies a large portion of the interior of the cell.

causes. Geotropic movements (Sect. 70) are due to the response of roots or shoots to gravitation. These

[1] See Pfeffer's *Physiology of Plants*, translated by Ewart, Vol. I, Introduction, "The Nature of Irritability."

movements are due to unequal growth induced in the younger portions of the plant by the action of gravitation upon it. Other movements (of ordinary foliage leaves, of the floral leaves of many flowers, and of other parts of a few flowers) are produced by changes in the distention or *turgescence* of some of the cells in the organs which move and have nothing to do with growth. The closing of the leaves of insect-catching plants is briefly described in Sect. 410, and the "sleep" of leaves, due to movements of the pulvini, was described in Sect. 152. A few facts in regard to the opening and closing of flowers will be found in Sect. 440.

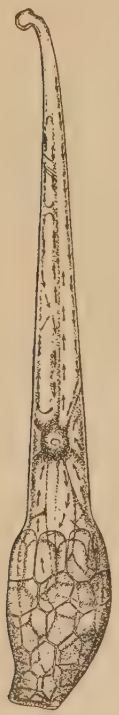


FIG. 127. — Stinging Hair of Nettle, with Nucleus. (Much magnified.) The arrows show the direction of the currents in the protoplasm.

The stimuli which cause movements of leaves or of the irritable parts of flowers are of several kinds. Light is the main cause which induces leaves to open from their night position to that usual in the daytime. In the case of flowers, it is sometimes light and sometimes warmth which causes them to open. Leaves which catch insects may be made to close by touching them, but the sensitive-plants, of which there are several kinds found in the United States, and a much more sensitive one in tropical America, all fold their leaflets, on being touched, into the same position which they assume at night.

195. Circulation of Protoplasm. — When confined by a cell-wall, protoplasm often manifests a beautiful and constant rotating movement, traveling incessantly up one side of the cell and down the other.[1] A more complicated motion is the *circulation of protoplasm*, shown in cells of the jointed blue hairs in the flower of the common spiderwort and in the stinging hairs of the nettle (Fig. 127). The thin cell-wall of each hair is lined with a protoplasmic layer in which are seen many irregular, thread-like currents, marked by the movements of the granules, of which the protoplasmic layer is full.

[1] See Huxley and Martin's *Elementary Biology*, under *Chara*.

CHAPTER XIII

INFLORESCENCE, OR ARRANGEMENT OF FLOWERS ON THE STEM

196. Regular Positions for Flower-Buds. — Flower-buds, like leaf-buds, occur regularly either in the axils of leaves or at the end of the stem or branch and are therefore either axillary or terminal.

197. Axillary and Solitary Flowers; Indeterminate Inflorescence. — The simplest possible arrangement for flowers which arise from the axils of leaves is to have a single flower spring from each leaf-axil. Fig. 128 shows how this plan appears in a plant with opposite leaves. As long as the stem continues to grow, the production of new leaves may be followed by that of new

FIG. 128. — Axillary and Solitary Flowers of Pimpernel.

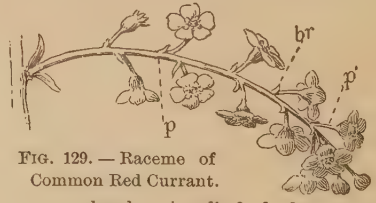


FIG. 129. — Raceme of Common Red Currant.
p, peduncle; *p'*, pedicel; *br*, bract.

flowers. Since there is no definite limit to the number of flowers which may appear in this way, the mode of flowering just described (with many others of the same general character) is known as *indeterminate inflorescence.*

198. The Racemes and Related Forms. — If the leaves along the stem were to become very much dwarfed and the flowers brought closer together, as they frequently are, a kind of flower-cluster like that of the currant (Fig. 129) or the lily-of-the-valley would result. Such an inflorescence is called a *raceme;* the main flower-stalk is known as the *peduncle;* the little individual flower-stalks are *pedicels*, and the small, more or less scale-like leaves of the peduncle are *bracts.*[1]

FIG. 130. — Simple Umbel of Cherry.

Frequently the lower pedicels of a cluster on the general plan of the raceme are longer than the upper ones and make a somewhat flat-topped cluster, like that of the hawthorn, the sheep laurel, or the trumpet creeper. This is called a *corymb.*

In many cases, for example the parsnip, the Sweet Cicely, the ginseng, and the cherry, a group of pedicels of nearly equal length

A *B*

FIG. 131. — Catkins of Willow.

A, staminate flowers; *B*, pistillate flowers.

[1] It is hardly necessary to say that the teacher will find it better in every way, if material is abundant, to begin the study of flower-clusters with the examination of typical specimens by the class.

spring from about the same point. This produces a flower-cluster called the *umbel* (Fig. 130).

199. Sessile Flowers and Flower-Clusters. — Often the pedicels are wanting, or the flowers are sessile, and then a modification of the raceme is produced which is called a *spike*, like that of the plantain (Fig. 132). The willow, alder, birch, poplar, and many other common trees bear a short, flexible, rather scaly spike (Fig. 131), which is called a *catkin*.

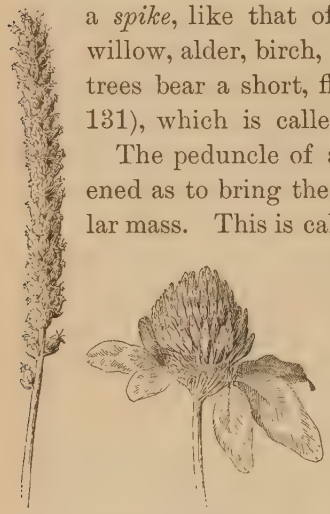


FIG. 132. — Spike of Plantain and Head of Red Clover.

The peduncle of a spike is often so much shortened as to bring the flowers into a somewhat globular mass. This is called a *head* (Fig. 132). Around the base of the head usually occurs a circle of bracts known as the *involucre*. The same name is given to a set of bracts which often surround the bases of the pedicels in an umbel.

200. The Composite Head. — The plants of one large group, of which the dandelion, the daisy, the thistle, and the sunflower are well-known members, bear their flowers in close involucrate heads on a common receptacle. The whole cluster looks so much like a single flower that it is usually taken for one by non-botanical people. In many of the largest and most showy heads, like that of the sunflower and the daisy, there are two kinds of flowers, the *ray-flowers*, around the margin, and the tubular *disk-flowers* of the interior of the head (Fig. 133). The early botanists supposed the whole flower-cluster to be a single

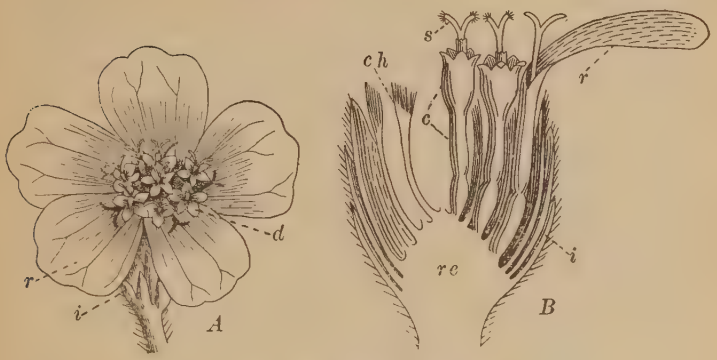


FIG. 133. — Head of Yarrow.

A, top view. (Magnified.) *B*, lengthwise section. (Magnified.) *re*, receptacle; *i*, involucre; *r*, ray-flowers; *d*, disk-flowers; *c*, corolla; *s*, stigma; *ch*, chaff, or bracts of receptacle.

FIG. 134.
Panicle of Oat.

FIG. 135. — Compound Umbel of Carrot.

compound flower. This belief gave rise to the name of one family of plants, *Compositæ*, that is, plants with compound flowers. In such heads as those of the thistle, the cud weed, and the everlasting there are no ray-flowers, and in others, like those of the dandelion and the chicory, all the flowers are ray-flowers.

201. Compound Flower-Clusters. — If the pedicels of a raceme branch, they may produce a compound raceme, or

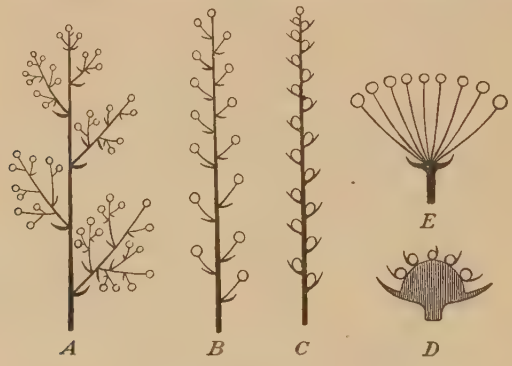


FIG. 136. — Diagrams of Inflorescence.
A, panicle; *B*, raceme; *C*, spike; *E*, umbel; *D*, head.

panicle, like that of the oat (Fig. 134).[1] Other forms of compound racemes have received other names.

An umbel may become compound by the branching of its flower-stalks (Fig. 135), each of which then bears a little umbel, an *umbellet*.

202. Inflorescence Diagrams. — The plan of inflorescence may readily be indicated by diagrams like those of Fig. 136.

The student should construct such diagrams for some rather complicated flower-clusters, like those of the grape, horse-chestnut or buckeye, hardhack, vervain, or many grasses.

[1] Panicles may also be formed by compound cymes (see Sect. 204).

203. Terminal Flowers; Determinate Inflorescence. — The terminal bud of a stem may be a flower-bud. In this case the direct growth of the stem is stopped or determined by the appearance of the flower; hence such plants are said to have a *determinate inflorescence*. The simplest possible case of this kind is that in which the stem bears but one flower at its summit.

204. The Cyme. — Very often flowers appear from lateral (axillary) buds, below the terminal flower, and thus give rise to a flower-cluster called a *cyme*. This may have only three flowers, and in that case would look very much like a three-flowered umbel. But in the raceme, corymb, and umbel the order of flowering is from below upward, or from the outside of the cluster inward, because the lowest or the outermost flowers are the oldest, while in determinate forms of inflorescence the central flower is the oldest, and therefore the order of blossoming is from the center outwards. Cymes are very commonly compound, like those of the elder and of many plants of the pink family, such as the Sweet William and the mouse-ear chickweed (Fig. 137). They may also, as already mentioned, be panicled, thus making a cluster much like Fig. 136, *A*.

FIG. 137. — Compound Cyme of Mouse-Ear Chickweed.
t, the terminal (oldest) flower.

CHAPTER XIV

THE STUDY OF TYPICAL FLOWERS

(Only one of the three flowers described to be studied by aid of these directions.)

205. The Flower of the Trillium. — Cut off the flower-stalk rather close to the flower; stand the latter, face down, on the table, and draw the parts then shown. Label the green leaf-like parts *sepals*, and the white parts, which alternate with these, *petals*. Turn the flower face up, and make another sketch, labeling the parts as before, together with the yellow enlarged extremities or *anthers* of the stalked organs called *stamens*.

Note and describe the way in which the petals alternate with the sepals. Observe the arrangement of the edges of the petals toward the base, — how many with both edges outside the others, how many with both edges inside, how many with one edge in and one out.

Note the veining of both sepals and petals, more distinct in which set?[1]

Pull off a sepal and make a sketch of it, natural size; then remove a petal, flatten it out, and sketch it, natural size.

Observe that the flower-stalk is enlarged slightly at the upper end into a rounded portion, the *receptacle*, on which all the parts of the flower rest.

Note how the six stamens arise from the receptacle and their relations to the origins of the petals. Remove the remaining petals

[1] In flowers with delicate white petals the distribution of the fibro-vascular bundles in these can usually be readily shown by standing the freshly cut end of the peduncle in red ink for a short time, until colored veins begin to appear in the petals. The experiment succeeds readily with apple, cherry, or plum blossoms; with white gilliflower the coloration is very prompt. Lily-of-the-valley is perhaps as interesting a flower as any on which to try the experiment, since the well-defined stained stripes are separated by portions quite free from stain, and the pistils are also colored.

(cutting them off near the bottom with a knife), and sketch the stamens, together with the other object, the *pistil*, which stands in the center.

Cut off one stamen, and sketch it as seen through the magnifying glass. Notice that it consists of a greenish stalk, the *filament*, and a broader portion, the *anther* (Fig. 149). The latter is easily seen to contain a prolongation of the green filament, nearly surrounded by a yellow substance. In the bud it will be found that the anther consists of two long pouches or *anther-cells*, which are attached by their whole length to the filament, and face inward (towards the center of the flower). When the flower is fairly open, the anther-cells have already split down their margins, and are discharging a yellow, somewhat sticky powder, the *pollen*.

Examine one of the anthers with the microscope, using the two-inch objective, and sketch it.

Cut away all the stamens, and sketch the *pistil*. It consists of a stout lower portion, the *ovary*, which is six-ridged or angled, and which bears at its summit three slender *stigmas*.

In another flower, which has begun to wither (and in which the ovary is larger than in a newly opened flower), cut the ovary across about the middle, and try to make out with the magnifying glass the number of chambers or *cells* which it contains. Examine the cross-section with the two-inch objective; sketch it, and note particularly the appearance and mode of attachment of the undeveloped seeds or *ovules* with which it is filled. Make a vertical section of another rather mature ovary, and examine this in the same way.

Using a fresh flower, construct a diagram to show the relation of the parts on an imaginary cross-section, as illustrated in Fig. 157.[1] Construct a diagram of a longitudinal section of the flower, on the general plan of those in Fig. 155, but showing the contents of the ovary.

Make a tabular list of the parts of the flower, beginning with the sepals, giving the order of parts and number in each set.

[1] It is important to notice that such a diagram is not a picture of the section actually produced by cutting through the flower crosswise at any one level, but that it is rather a *projection* of the sections through the most typical part of each of the floral organs.

206. The Flower of the Tulip.[1] — Make a diagram of a side view of the well-opened flower, as it appears when standing in sunlight. Observe that there is a set of outer flower-leaves and a set of inner ones.[2] Label the outer set *sepals* and the inner set *petals*. In most flowers the parts of the outer set are greenish, and those of the inner set of some other color. It is often convenient to use the name *perianth*, meaning around the flower, for the two sets taken together. Note the white waxy bloom on the outer surface of the outer segments of the perianth. What is the use of this? Note the manner in which the inner segments of the perianth arise from the top of the peduncle and their relation to the points of attachment of the outer segments. In a flower not too widely opened, note the relative position of the inner segments of the perianth, how many wholly outside the other two, how many wholly inside, how many with one edge in and one edge out.

Remove one of the sepals by cutting it off close to its attachment to the peduncle, and examine the veining by holding it up in a strong light and looking through it. Make a sketch to show the general outline and the shape of the tip.

Examine a petal in the same way, and sketch it.

Cut off the remaining portions of the perianth, leaving about a quarter of an inch at the base of each segment. Sketch the upright, triangular, pillar-like object in the center, label it *pistil*, sketch the organs which spring from around its base, and label these *stamens*.

Note the fact that each stamen arises from a point just above and within the base of a segment of the perianth. Each stamen consists of a somewhat conical or awl-shaped portion below, the *filament*, surmounted by an ovate linear portion, the *anther*. Sketch one of the stamens about twice natural size and label it × 2. Is the attachment of the anther to the filament such as to admit of any nodding or twisting movement of the former? In a young flower, note the two tubular pouches or anther-cells of which the anther is composed, and the slits by which these open. Observe the dark-colored *pollen*

[1] *Tulipa Gesneriana*. As the flowers are rather expensive, and their parts are large and firm, it is not absolutely necessary to give a flower to each pupil, but some may be kept entire for sketching and others dissected by the class. All the flowers must be single.

[2] Best seen in a flower which is just opening.

which escapes from the anther-cells and adheres to paper or to the fingers. Examine a newly opened anther with the microscope, using the two-inch objective, and sketch it.

Cut away all the stamens and note the two portions of the pistil, a triangular prism, the *ovary*, and three roughened scroll-like objects at the top, the three lobes of the *stigma*. Make a sketch of these parts about twice natural size, and label them × 2. Touch a small camel's-hair pencil to one of the anthers, and then transfer the pollen thus removed to the stigma. This operation is merely an imitation of the work done by insects which visit the flowers out of doors. Does the pollen cling readily to the rough stigmatic surface? Examine this adhering pollen with the two-inch objective, and sketch a few grains of it, together with the bit of the stigma to which it clings. Compare this drawing with Fig. 162. Make a cross-section of the ovary about midway of its length, and sketch the section as seen through the magnifying glass. Label the three chambers shown *cells of the ovary* [1] or *locules*, and the white egg-shaped objects within *ovules*.[2]

Make a longitudinal section of another ovary, taking pains to secure a good view of the ovules, and sketch as seen through the magnifying glass.

Making use of the information already gained and the cross-section of the ovary as sketched, construct a diagram of a cross-section of the entire flower on the same general plan as those shown in Fig. 157.[3]

Split a flower lengthwise,[4] and construct a longitudinal section of the entire flower on the plan of those shown in Fig. 155, but showing the contents of the ovary.

207. The Flower of the Buttercup. — Make a diagram of the mature flower as seen in a side view, looking a little down into it. Label the pale greenish-yellow, hairy, outermost parts *sepals*, and

[1] Notice that the word *cell* here means a comparatively large cavity, and is not used in the same sense in which we speak of a wood-cell or a pith-cell.

[2] The section will be more satisfactory if made from an older flower, grown out of doors, from which the perianth has fallen. In this case label the contained objects *seeds*.

[3] Consult also the footnote on p. 193.

[4] One will do for an entire division of the class.

the larger bright yellow parts above and within these *petals*, and the yellow-knobbed parts which occupy a good deal of the interior of the flower *stamens*.

Note the difference in the position of the sepals of a newly opened flower and that of the sepals of a flower which has opened as widely as possible. Note the way in which the petals are arranged in relation to the sepals. In an opening flower observe the arrangement of the edges of the petals, how many entirely outside the others, how many entirely inside, how many with one edge in and the other out.

Cut off a sepal and a petal, each close to its attachment to the flower; place both, face down, on a sheet of paper, and sketch about twice the natural size and label it × 2. Describe the difference in appearance between the outer and the inner surface of the sepal and of the petal. Note the little scale at the base of the petal, inside.

Strip off all the parts from a flower which has lost its petals, until nothing is left but a slender conical object a little more than an eighth of an inch in length. This is the *receptacle* or summit of the peduncle.

In a fully opened flower, note the numerous yellow-tipped *stamens*, each consisting of a short stalk, the *filament*, and an enlarged yellow knob at the end, the *anther*. Note the division of the anther into two portions, which appear from the outside as parallel ridges, but which are really closed tubes, the *anther-cells*.

Observe in the interior of the flower the somewhat globular mass (in a young flower almost covered by the stamens). This is a group of *pistils*. Study one of these groups in a flower from which the stamens have mostly fallen off, and make an enlarged sketch of the head of pistils. Remove some of the pistils from a mature head, and sketch a single one as seen with the magnifying glass. Label the little knob or beak at the upper end of the pistil *stigma*, and the main body of the pistil the *ovary*. Make a section of one of the pistils, parallel to the flattened surfaces, like that shown in Fig. 150, and note the partially matured seed within.

CHAPTER XV

PLAN AND STRUCTURE OF THE FLOWER AND ITS ORGANS

208. Parts or Organs of the Flower. — Most showy flowers consist, like those studied in the preceding chapter, of four circles or sets of organs, the sepals, petals, stamens, and pistils. The sepals, taken together, constitute the *calyx;* the petals, taken together, constitute the *corolla* (Fig. 138).[1] Sometimes it is convenient to have a word to comprise both calyx and corolla; for this the term *perianth* is used. A flower which contains all four of these sets is said to be *complete.* Since the work of the flower is to produce seed, and seed-forming is due to the coöperation of stamens and pistils, or, as they are often called from their relation to the reproductive organs of spore-plants, *microsporophylls* and *macrosporophylls* (see Sect. 374), these are known as the *essential organs* (Fig. 138). The simplest possible pistil is a dwarfed and

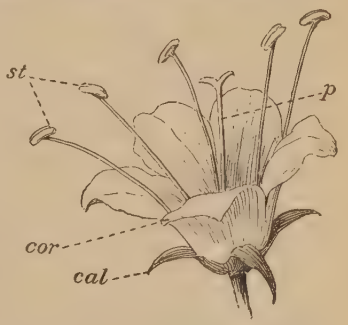


FIG. 138. — The Parts of the Flower. *cal*, calyx; *cor*, corolla; *st*, stamens; *p*, pistil.

[1] The flower of the waterleaf *Hydrophyllum canadense*, modified by the omission of the hairs on the stamens, is here given because it shows so plainly the relation of the parts.

greatly modified leaf (Sect. 222), adapted into a seed-bearing organ. Such a pistil may be one-seeded, as in Fig. 166, or several-seeded, as in the diagrammatic one (Fig. 150); it is called a *carpel*. The calyx and corolla are also known as the *floral envelopes*. Flowers which have the essential organs are called *perfect flowers*. They may, therefore, be perfect without being complete. Incomplete flowers with only one row of parts in the perianth are said to be *apetalous* (Fig. 139).

FIG. 139. — Apetalous Flower of (European) Wild Ginger.

209. Regular and Symmetrical Flowers. — A flower is *regular* if all the parts of the same set or circle are alike in size and shape, as in the stonecrop (Fig. 140). Such flowers as that of the violet, the monkshood, and the sweet pea (Fig. 141) are irregular. *Symmetrical* flowers are those whose calyx, corolla, circle of stamens, and set of carpels consist each of the same number of parts, or in which the number in every case is a multiple of the smallest number found in any set. The stonecrop is

FIG. 140. — Flower of Stonecrop.
I, entire flower (magnified); II, vertical section (magnified).

symmetrical, since it has five sepals, five petals, ten stamens, and five carpels. Roses, mallows, and mignonette

are familiar examples of flowers which are unsymmetrical because they have a large, indefinite number of stamens ; the portulaca is unsymmetrical, since it has two divisions of the calyx, five or six petals, and seven to twenty stamens.

210. The Receptacle. — The parts of the flower are borne on an expansion of the peduncle, called the *receptacle*. Usually, as in the flower of the grape (Fig. 250), this is only a slight enlargement of the peduncle, but in

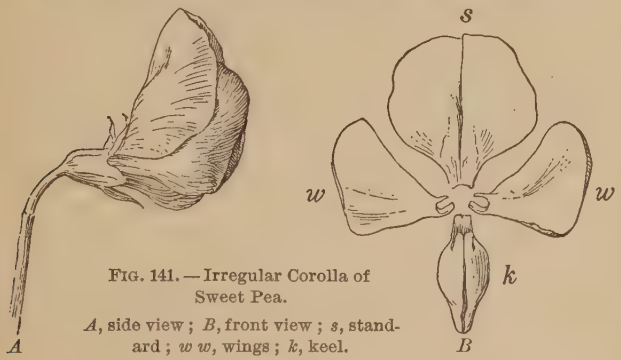


FIG. 141. — Irregular Corolla of Sweet Pea.
A, side view ; *B*, front view ; *s*, standard ; *w w*, wings ; *k*, keel.

the lotus and the magnolia the receptacle is of great size, particularly after the petals have fallen and the seed has ripened. The receptacle of the rose (Fig. 142) is hollow, and the pistils arise from its interior surface.

211. Imperfect or Separated Flowers. — The stamens and pistils may be produced in separate flowers, which are, of course, *imperfect*. This term does not imply that such flowers do their work any less perfectly than others, but only that they have not both kinds of essential organs. In the very simple imperfect flowers of the willow (Fig. 143) each flower of the catkin (Fig. 131) consists merely

of a pistil or a group of (usually two) stamens, springing from the axil of a small bract.

Staminate and pistillate flowers may be borne on different plants, as they are in the willow, or they may be borne on the same plant, as in the hickory and the hazel, among trees, or in the castor-oil plant, Indian corn, and the begonias. When staminate and pistillate flowers are borne on separate plants, such a plant is said to be *dicœcious*, that is, of two households; when both kinds of flower appear on the same individual, the plant is said to be *monœcious*, that is, of one household.

212. Study of Imperfect Flowers. — Examine, draw, and describe the imperfect flowers of some of the following dicœcious plants and one of the monœcious plants:[1]

Dicœcious plants	early meadow rue.
	willow.
	poplar.
Monœcious plants	walnut, oak, chestnut.
	hickory, alder, beech.
	birch, hazel, begonia.

213. Union of Similar Parts of the Perianth. — The sepals may appear to join or *cohere* to form a calyx which is more or less entirely united into one piece, as in Figs. 139 and 148. In this case the calyx is said to be *gamosepalous*, that is, of wedded sepals. In the same way the corolla is frequently *gamopetalous*, as in Figs. 144–148. Frequently the border or *limb* of the calyx or corolla is more or less cut or lobed. In this case the projecting

[1] For figures or descriptions of these or allied flowers consult Gray's *Manual of Botany*, Emerson's *Trees and Shrubs of Massachusetts*, Newhall's *Trees of the Northern United States*, or Le Maout and Decaisne's *Traité Général de Botanique*.

portions of the limb are known as divisions, teeth, or lobes.[1] Special names of great use in accurately describing plants are given to a large number of forms of the gamopetalous corolla. Only a few of these names are here given, in connection with the figures.

FIG. 142. A Rose, Longitudinal Section.

When the parts of either circle of the perianth are wholly unconnected with each other, that is, polysepalous or polypetalous, such parts are said to be *distinct*.

214. Parts of the Stamen and the Pistil. — The stamen usually consists of a hollow portion, the *anther* (Fig. 149, *a*), borne on a stalk called the *filament* (Fig. 149, *f*), which is often lacking. Inside the anther is a powdery or pasty substance called *pollen* or *microspores* (Sect. 374). The pistil usually consists of a small chamber, the *ovary*, which contains the *ovules*, *macrospores* (Sect. 374), or rudimentary seeds, a slender portion or stalk, called the *style*, and at the top of this a ridge, knob, or point called the *stigma*. These parts are all shown in Fig. 150. In many pistils the stigma is borne directly on the ovary.

FIG. 143. — Flowers of Willow. (Magnified.)
A, staminate flower; *B*, pistillate flower.

215. Union of Stamens with Each Other. — Stamens may be wholly unconnected with

[1] It would not be safe to assume that the gamosepalous calyx or the gamopetalous corolla is really formed by the union of separate portions, but it is very convenient to speak of it as if it were.

each other or *distinct*, or they may cohere by their filaments into a single group, when they are said to be *monadelphous*, of one brotherhood (Fig. 151), into two groups (*diadelphous*) (Fig. 152), or into many groups. In some flowers the stamens are held together in a ring by their coherent anthers (Fig. 153).

FIG. 144. — Bell-Shaped Corolla of Bell-Flower (*Campanula*).

216. Union of Pistils. — The pistils may be entirely separate from each other, *distinct* and *simple*, as they are in the buttercup and the stonecrop, or several may join to form one *compound pistil* of more or less united carpels. In the latter case the union generally affects the ovaries, but often leaves the styles separate, or it may result in joining ovaries and styles, but leave the stigmas separate or at any rate lobed, so as to show of how many separate carpels the compound pistil is made up. Even when there is no external sign to show the compound nature of the pistil, it can usually be recognized from the study of a cross-section of the ovary.

FIG. 145. — Salver-Shaped Corolla of Jasmine. (Magnified.)

FIG. 146. Wheel-Shaped Corolla of Potato.

217. Cells of the Ovary; Placentas. — Compound ovaries are very commonly several-celled, that is, they consist of a number of

separate cells[1] or chambers, more scientifically known as *locules.* Fig. 154, *B*, shows a three-celled ovary seen in cross-section. The ovules are not borne indiscriminately by any part of the lining of the ovary. In one-celled pistils they frequently grow in a line running along one side of the ovary, as in the pea pod (Fig. 271). The ovule-bearing line is called a *placenta;* in compound pistils there are commonly as many placentas as there are

FIG. 147. — Tubular Corolla, from Head of Bachelor's Button.

FIG. 148. — Labiate or Ringent Corolla of Dead Nettle.

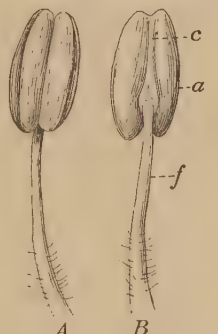


FIG. 149. — Parts of a Stamen.
A, front; *B*, back; *a*, anther; *c*, connective; *f*, filament.

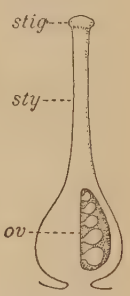


FIG. 150. — Parts of the Pistil.
ov, ovary.
sty, style.
stig, stigma.

separate pistils joined to make the compound one. Placentas on the wall of the ovary, like those in Fig. 154, *A*, are called *parietal placentas;* those which occur as at *B*, in the same figure, are said to be central, and those which, like the form represented in *C* of the same figure, consist of a column rising from the bottom of the ovary are called *free central placentas.*

[1] Notice that the word *cell* is here used in an entirely different sense from that in which it has been employed in the earlier chapters of this book. As applied to the ovary, it means a chamber or compartment.

218. Union of Separate Circles. — The members of one of the circles of floral organs may join those of another circle, thus becoming *adnate*, *adherent*, or *consolidated*.

FIG. 151. Monadelphous Stamens of Mallow.

In Fig. 139 the calyx tube is adnate to the ovary. In this case the parts of the flower do not all appear to spring from the receptacle. Fig. 155 illustrates three common cases as regards insertion of the parts of the flower. In I they are all inserted on the receptacle, and the corolla and stamens are said to be *hypogynous*, that is, beneath the pistil. In II the petals and the stamens appear as if they had grown fast to the calyx for some distance, so that they surround the pistil, and they are therefore said to be *perigynous*, that is, around the pistil. In III all the parts are *free* or unconsolidated, except the petals and stamens; the stamens may be described as *epipetalous*, that is, growing on the petals.

FIG. 152. — Diadelphous Stamens of Sweet Pea.

Sometimes some or all of the other parts stand upon the ovary, and such parts are said to be *epigynous*, that is, on the ovary, like the petals and stamens of the white water-lily (Fig. 156).

FIG. 153. — Stamens of a Thistle, with Anthers united into a Ring.

a, united anthers; *f*, filaments, bearded on the sides.

219. Floral Diagrams. — Sections (real or imaginary) through the flower lengthwise, like those of Fig. 155, help greatly in giving an accurate idea of the relative position of the floral organs. Still more

important in this way are cross-sections, which may be recorded in diagrams like those of Fig. 157.[1] In constructing such diagrams it will often be necessary to suppose some of the parts of the flower to be raised or lowered from their true position, so as to bring them into such relations that all could be cut by a single section. This would, for instance, be necessary in making a diagram for the cross-section of the flower

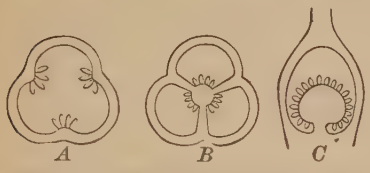


FIG. 154. — Principal Types of Placenta.

A, parietal placenta; *B*, central placenta; *C*, free central placenta; *A* and *B*, transverse sections; *C*, longitudinal section.

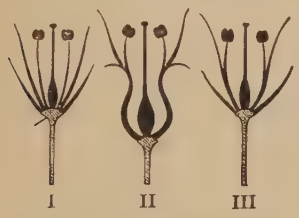


FIG. 155. — Insertion of the Floral Organs.

I, Hypogynous, all the other parts on the receptacle, beneath the pistil; II, Perigynous, petals and stamens apparently growing out of the calyx, around the pistil; III, corolla hypogynous, stamens epipetalous.

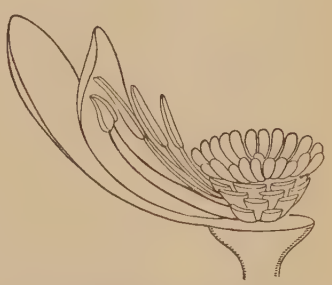


FIG. 156. — White Water-Lily. The inner petals and the stamens growing from the ovary.

of the white water-lily, of which a partial view of one side is shown in Fig. 156.[2]

[1] For floral diagrams see Le Maout and Decaisne's *Traité Général de Botanique*, or Eichler's *Blüthendiagramme*.

[2] It is best to begin practice on floral diagrams with flowers so firm and large that actual sections of them may be cut with ease and the relations of the parts in the section readily made out. The tulip is admirably adapted for this purpose.

Construct diagrams of the longitudinal section and the transverse section of several large flowers, following the method indicated in Figs. 155 and 157, but making the longitudinal section show the interior of the ovary.[1] It is found convenient to distin-

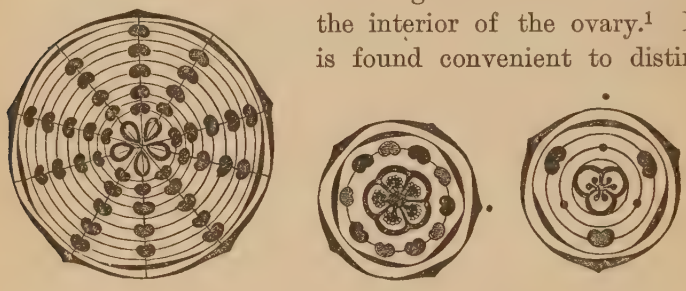


FIG. 157. — Diagram of Cross-Sections of Flowers.

I, columbine ; II, heath family ; III, iris family. In each diagram the dot alongside the main portion indicates a cross-section of the stem of the plant. In II every other stamen is more lightly shaded, because some plants of the heath family have five and some ten stamens.

guish the sepals from the petals by representing the former with midribs. The diagrammatic symbol for a stamen stands for a cross-section of the anther, and that for the pistil is a section of the ovary. If any part is lacking in the flower (as in the case of flowers which have some antherless filaments) the missing or abortive organ may be indicated by a dot. In the diagram of the Iris Family (Fig. 157, III) the three dots inside the flower indicate the position of a second circle of stamens, found in most flowers of monocotyledons but *not* found in this family.

[1] Among the many excellent early flowers for this purpose may be mentioned trillium, bloodroot, dogtooth violet, marsh marigold, buttercup, tulip tree, horse-chestnut, Jeffersonia, May-apple, cherry, apple, crocus, tulip, daffodil, primrose, wild ginger, cranesbill, locust, bluebell.

220. Review Summary of Chapter XV.[1]

Kinds of flowers as regards number of circles or sets of organs present . . . . . { 1. 2. 3. 4.

Kinds as regards numerical plan . . . . . { 1. 2.

Kinds as regards similarity of parts of the same circle . . . . . { 1. 2.

Parts of a stamen . . . . . { 1. 2.

Parts of a pistil . . . . . { 1. 2. 3.

Stamens as regards union with each other . . . { 1. 2. 3. 4.

Pistils as regards union with each other . . . . { 1. 2.

Degree of union of separate circles . . . . . {

[1] Illustrate by sketches.

CHAPTER XVI

TRUE NATURE OF FLORAL ORGANS; DETAILS OF THEIR STRUCTURE; FERTILIZATION

221. The Flower a Shortened and greatly Modified Branch. — In Chapter VIII, the leaf-bud was explained as being an undeveloped branch, which in its growth would develop into a real branch (or a prolongation of the main stem). Now, since flower-buds appear regularly

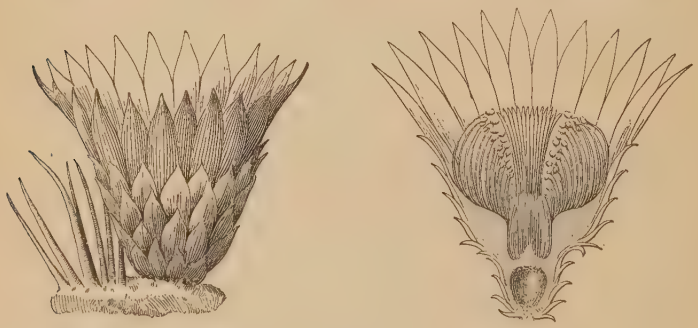


FIG. 158. — Transition from Bracts to Sepals in a Cactus Flower.

either in the axils of leaves or as terminal buds, there is reason to regard them as of similar nature to leaf-buds. This would imply that the receptacle corresponds to the axis of the bud shown in Fig. 86, and that the parts of the flower correspond to leaves. There is plenty of evidence that this is really true. Sepals frequently look very much like leaves, and in many cacti the bracts

about the flower are so sepal-like that it is impossible to tell where the bracts end and the sepals begin (Fig. 158). The same thing is true of sepals and petals in such flowers as the white water-lily. In this flower there is a remarkable series of intermediate steps, ranging all the way from petals, tipped with a bit of anther, through stamens with a broad petal-like filament, to regular stamens, as is shown in Fig. 159, *E*, *F*, *G*, *H*. The same thing is shown in

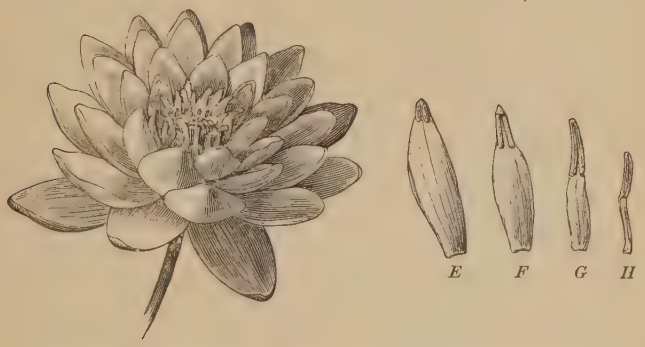


FIG. 159. — Transitions from Petals to Stamens in White Water-Lily.
E, *F*, *G*, *H*, various steps between petal and stamen.

many double roses. In completely double flowers all the *essential* organs are transformed by cultivation into petals. In the flowers of the cultivated double cherry the pistils occasionally take the form of small leaves, and some roses turn wholly into green leaves.

Summing up, then, we know that flowers are altered and shortened branches : (1) because flower-buds have as regards position, the same kind of origin as leaf-buds; (2) because all the intermediate steps are found between bracts, on the one hand, and stamens, on the other ; (3)

because the essential organs are found to be replaced by petals or even by green leaves.

The fact that leaves should be so greatly modified as they are in flowers and given work to do wholly different from that of the other kinds of leaves so far studied need not strike one as exceptional. In many of the most highly developed plants below the seed-plants, organs corresponding to flowers are found, and these consist of modified leaves, set apart for the work of reproducing (Sect. 367).

222. Mode of Formation of Stamens and Pistils from Leaves. — It is hardly possible to state, until after Chapter XXIII has been studied, how stamens stand related to leaves.[1]

The simple pistil or *carpel* is supposed to be made on the plan of a leaf folded along the midrib until its margins touch, like the cherry leaf in Fig. 87. But the student must not understand by this statement that the little pistil leaf grows at first like an ordinary leaf and finally becomes folded in. The united leaf-margins near the tip would form the stigma, and the placenta would correspond to the same margins, rolled slightly inwards, extending along the inside of the inflated leaf-pouch. Place several such folded leaves upright about a common center, and their cross-section would be much like that of *B* in Fig. 154. Evidence that carpels are really formed in this way may be gained from the study of such fruits as that of the monkshood (Fig. 168), in which the ripe carpels may be seen to unfold into a shape much more leaf-like than that which they had while the pistil was maturing. What

[1] "The anther answers exactly to the spore-cases of the ferns and their allies, while the filament is a small specialized leaf to support it." For a fuller statement, see Potter and Warming's *Systematic Botany*, pp. 236, 237.

really occurs is this: the flower-bud, as soon as it has developed far enough to show the first rudiments of the essential organs, contains them in the form of minute knobs. These are developed from the tissues of the plant in the same manner as are the knobs in a leaf-bud, which afterwards become leaves (Fig. 87, II); but as growth and development progress in the flower-bud, its contents soon show themselves to be stamens and pistils (if the flower is a perfect one).

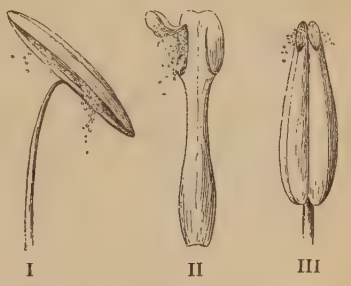


FIG. 160.—Modes of discharging Pollen.

I, by longitudinal slits in the anther-cells (amaryllis); II, by uplifted valves (barberry); III, by a pore at the top of each anther-lobe (nightshade).

223. The Anther and its Contents.—Some of the shapes of the anthers may be learned from Figs. 149 and 160.[1] The shape of the anther and the way in which it opens depend largely upon the way in which the pollen is to be discharged and how it is carried from flower to flower. The commonest method is to have the anther-cells split lengthwise, as in Fig. 160, I. A few anthers open by trap-doors like valves, as in II, and a larger number by little holes at the top, as in III.

The pollen in many plants with inconspicuous flowers, as the evergreen cone-bearing trees, the grasses, rushes, and sedges, is a fine, dry powder. In plants with showy flowers it is often somewhat sticky or pasty. The forms of pollen grains are extremely various. Fig. 161 will serve to furnish examples of some of the shapes which

[1] See Kerner and Oliver's *Natural History of Plants*, Vol. II, pp. 86–95.

the grains assume; *c* in the latter figure is perhaps as common a form as any. Each pollen grain consists mainly of a single cell, and is covered by a moderately thick outer wall and a thin inner one. Its contents are thickish protoplasm, full of little opaque particles and usually containing grains of starch and little drops of oil. The knobs on the outer coat, as shown in Fig. 161 *b*, mark

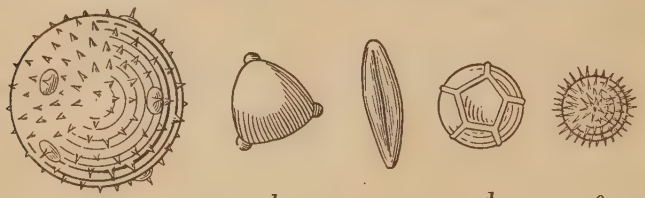


FIG. 161. — Pollen Grains. (Very greatly magnified.)
a, pumpkin; *b*, enchanter's nightshade; *c*, Albuca; *d*, pink; *e*, hibiscus.

the spots at which the inner coat of the grain is finally to burst through the outer one, pushing its way out in the form of a slender, thin-walled tube.[1]

224. The Formation of Pollen Tubes. — This can be studied in pollen grains which have lodged on the stigma and there been subjected to the action of its moist surface. It is, however, easier to cause the artificial production of the tubes.

EXPERIMENT XXXVIII

Production of Pollen Tubes. — Place a few drops of suitably diluted syrup with some fresh pollen in a concave cell ground in a microscope slide; cover with thin glass circle; place under a bell-glass, with a wet cloth or sponge, to prevent evaporation of the syrup, and set aside in a warm place, or merely put some pollen in syrup in a

[1] See Kerner and Oliver's *Natural History of Plants*, Vol. II, pp. 95–104.

watch crystal under the bell-glass. Examine from time to time to note the appearance of the pollen tubes. Try several kinds of pollen if possible, using syrups of various strengths. The following kinds of pollen form tubes readily in syrups of the strengths indicated.

Tulip	1 to 3 per cent.
Narcissus	3 to 5 "
Cytisus canariensis (called Genista by florists)	15 "
Chinese primrose	10 "
Sweet pea [1]	10 to 15 "
Tropæolum [1]	15 "

225. Microscopical Structure of the Stigma and Style. — Under a moderate power of the microscope the stigma is seen to consist of cells set irregularly over the surface, and secreting a viscid liquid to which the pollen grains adhere (Fig. 162). Beneath these superficial cells and running down through the style (if there is one) to the ovary is spongy parenchyma. In some pistils the pollen tube proceeds through the cell walls, which it softens by means of a substance which it exudes for that purpose. In other cases (Fig. 163) there is a canal or passage, along which the pollen tube travels on its way to the ovule.

FIG. 162. — Stigma of Thorn-Apple (*Datura*) with Pollen. (Magnified.)

[1] The sweet-pea pollen and that of Tropæolum are easier to manage than any other kinds of which the author has personal knowledge. If a concaved slide is not available, the cover-glass may be propped up on bits of the thinnest broken cover-glasses. From presence of air or some other reason, the formation of pollen tubes often proceeds most rapidly just inside the margin of the cover-glass.

226. Fertilization. — Fertilization in seed-plants means the union of a sperm nucleus derived from a generative cell of a pollen grain with an egg-cell at the apex of the *embryo sac* (Fig. 165). This process gives rise to a cell which contains material derived from the pollen and from the egg-cell. In a great many plants the pollen, in order to accomplish the most successful fertilization, must come from another plant of the same kind, not from the individual which bears the ovules that are being fertilized.

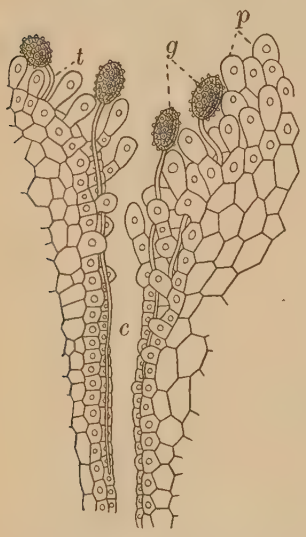


FIG. 163. — Pollen Grains producing Tubes, on Stigma of a Lily. (Much magnified.)

g, pollen grains; *t*, pollen tubes; *p*, papillæ of stigma; *c*, canal or passage running toward ovary.

FIG. 164. — Pollen Grain of Snowflake (*Leucoium*) producing a Pollen Tube with Two Male or Sperm Cells.

Pollen tubes begin to form soon after pollen grains lodge on the stigma. The time required for the process to begin varies in different kinds of plants, requiring in many cases twenty-four hours or more. The length of time needed for the pollen tube to make its way through the style to the ovary depends upon the length of the style and other conditions. In the crocus, which has a style several inches long, the descent takes from one to three days.

Finally the tube penetrates the opening at the apex of

the ovule *m*, in Fig. 165, reaches one of the cells shown at *e*, and transfers a male cell into this egg-cell. The latter is thus enabled to divide and grow rapidly into an embryo. This the cell does by forming cell-walls and then increasing by continued subdivision, in much the same way in which the cells at the growing point near the tip of the root, or those of the cambium layer, subdivide.[1]

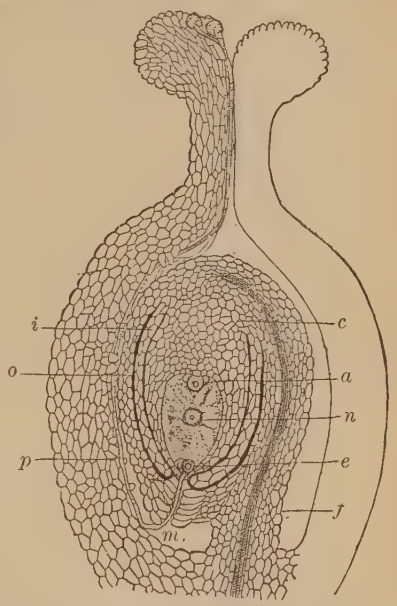


FIG. 165. — Diagrammatic Representation of Fertilization of an Ovule.

i, inner coating of ovule; *o*, outer coating of ovule; *p*, pollen tube, proceeding from one of the pollen grains on the stigma; *c*, the place where the two coats of the ovule blend. (The kind of ovule here shown is inverted, its opening *m* being at the bottom, and the stalk *f* adhering along one side of the ovule.) *a* to *e*, embryo sac, full of protoplasm; *a*, so-called antipodal cells of embryo sac; *n*, central nucleus of the embryo sac; *e*, nucleated cells, one of which, the egg-cell, receives the essential contents of the pollen tube; *f*, funiculus or stalk of ovule; *m*, opening into the ovule.

227. Nature of the Fertilizing Process. — The necessary feature of the process of fertilization is *the union of the essential contents of two cells to form a new one, from which the future plant is to spring*. This kind of union is found to occur in many cryptogams (Chapters XX–XXII), resulting in the production of a spore capable of growing into a complete plant like that which produced it.

[1] See Kerner and Oliver's *Natural History of Plants*, Vol. II, pp. 401–420.

228. Number of Pollen Grains to Each Ovule. — Only one pollen tube is necessary to fertilize each ovule, but so many pollen grains are lost that plants produce many more of them than of ovules. The ratio, however, varies greatly. In the night-blooming cereus there are about 250,000 pollen grains for 30,000 ovules, or rather more than 8 to 1, while in the common garden wistaria there are about 7000 pollen grains to every ovule, and in Indian corn, the cone-bearing evergreens, and a multitude of other plants, many times more than 7000 to 1. These differences depend upon the mode in which the pollen is carried from the stamens to the pistil.

CHAPTER XVII

THE STUDY OF TYPICAL FRUITS

229. A Berry, the Tomato.[1] — Study the external form of the tomato, and make a sketch of it showing the persistent calyx and peduncle.

Cut a cross-section at about the middle of the tomato. Note the thickness of the epidermis (peel off a strip) and of the wall of the ovary. Note the number, size, form, and contents of the cells of the ovary. Observe the thickness and texture of the partitions between the cells. Sketch.

Note the attachments of the seeds to the placentas and the gelatinous, slippery coating of each seed.

The tomato is a typical berry, but its structure presents fewer points of interest than are found in some other fruits of the same general character, so the student will do well to spend a little more time on the examination of such fruits as the orange or the lemon.

230. A Hesperidium, the Lemon. — Procure a large lemon which is not withered, if possible one which still shows the remains of the calyx at the base of the fruit.

Note the color, general shape, surface, remains of the calyx, knob at portion formerly occupied by the stigma. Sketch the fruit about natural size. Examine the pitted surface of the rind with the magnifying glass and sketch it. Remove the bit of stem and dried-up calyx from the base of the fruit; observe, above the calyx, the knob or *disk* on which the pistil stood. Note with the magnifying glass and count the minute whitish raised knobs at the bottom of the saucer-shaped depression left by the removal of the disk. What are they?

[1] Fresh tomatoes, not too ripe, are to be used, or those which have been kept over from the previous summer in formalin solution. The very smallest varieties, such as are often sold for preserving, are as good for study as the larger kinds.

Make a transverse section of the lemon, not more than a fifth of the way down from the stigma end and note :

(1) The thick skin, pale yellow near the outside, white within.

(2) The more or less wedge-shaped divisions containing the juicy pulp of the fruit. These are the matured cells of the ovary ; count these.

(3) The thin partition between the cells.

(4) The central column or axis of white pithy tissue.

(5) The location and attachment of any seeds that may be encountered in the section.

Make a sketch to illustrate these points, comparing it with Fig. 171.

Study the section with the magnifying glass and note the little spherical reservoirs near the outer part of the skin, which contain the oil of lemon which gives to lemon peel its characteristic smell and taste. Cut with the razor a thin slice from the surface of a lemon peel, some distance below the section, and at once examine the freshly cut surface with a magnifying glass to see the reservoirs, still containing oil, which, however, soon evaporates. On the cut surface of the pulp (in the original cross-section) note the tubes in which the juice is contained. These tubes are not cells, but their walls are built of cells. Cut a fresh section across the lemon, about midway of its length and sketch it, bringing out the same points which were shown in the previous one. The fact that the number of ovary cells in the fruit corresponds with the number of minute knobs in the depression at its base is due to the fact that these knobs mark the points at which fibro-vascular bundles passed from the peduncle into the cells of the fruit, carrying the sap by which the growth of the latter was maintained.

Note the toughness and thickness of the seed-coats. Taste the kernel of the seed.

Cut a very thin slice from the surface of the skin, mount in water, and examine with a medium power of the microscope. Sketch the cellular structure shown and compare it with the sketch of the corky layer of the bark of the potato tuber.

Of what use to the fruit is a corky layer in the skin? (See Sect. 453 for further questions.)

231. A Legume, the Bean-Pod.[1] — Lay the pod flat on the table and make a sketch of it, about natural size. Label *stigma*, *style*, *ovary*, *calyx*, *peduncle*.

Make a longitudinal section of the pod, at right angles to the plane in which it lay as first sketched, and make a sketch of the section, showing the partially developed seeds, the cavities in which they lie, and the solid portion of the pod between each bean and the next.

Split another pod, so as to leave all the beans lying undisturbed on one-half of it and sketch that half, showing the beans lying in their natural position and the *funiculus* or stalk by which each is attached to the *placenta;* compare Fig. 271.

Make a cross-section of another pod, through one of the beans, sketch the section, and label the placenta (formed by the united edges of the pistil leaf) and the midrib of the pistil leaf.

Break off sections of the pod and determine, by observing where the most stringy portions are found, where the fibro-vascular bundles are most numerous.

Examine some ripe pods of the preceding year,[2] and notice where the *dehiscence*, or splitting open of the pods, occurs, whether down the placental edge, *ventral suture*, the other edge, *dorsal suture*, or both.

232. An Akene, the Fruit of Dock. — Hold in the forceps a ripe fruit of any of the common kinds of dock,[3] and examine with the magnifying glass. Note the three dry, veiny, membranaceous sepals by which the fruit is enclosed. On the outside of one or more of the sepals is found a tubercle or thickened appendage which looks like a little seed or grain. Cut off the tubercles from several of the fruits, put these, with some uninjured ones, to float in a pan of water, and watch their behavior for several hours. What is apparently the use of the tubercle?

[1] Any species of bean (*Phaseolus*) will answer for this study. Specimens in the condition known at the markets as "shell-beans" would be best, but these are not obtainable in spring. Ordinary "string-beans" will do.

[2] Which may be passed round for that purpose. They should have been saved and dried the preceding autumn.

[3] *Rumex crispus*, *R. obtusifolius*, or *R. verticillatus*. This should have been gathered and dried the preceding summer.

Of what use are the sepals, after drying up? Why do the fruits cling to the plant long after ripening?

Carefully remove the sepals and examine the fruit within them. What is its color, size, and shape? Make a sketch of it as seen with the magnifying glass. Note the three tufted stigmas, attached by slender threads to the apex of the fruit. What does their tufted shape indicate?

What evidence is there that this seed-like fruit is not really a seed?

Make a cross-section of a fruit and notice whether the wall of the ovary can be seen, distinct from the seed-coats. Compare the dock fruit in this respect with the fruit of the buttercup, shown in Fig. 166. Such a fruit as either of these is called an *akene*.

CHAPTER XVIII

THE FRUIT[1]

233. What constitutes a Fruit. — It is not easy to make a short and simple definition of what botanists mean by the term *fruit*. It has very little to do with the popular use of the word. Briefly stated, the definition may be given as follows: *The fruit consists of the matured ovary and contents, together with any intimately connected parts.* Botanically speaking, the bur of beggar's ticks (Fig. 273), the three-cornered grain of buckwheat, or such true grains as wheat and oats, are as much fruits as is an apple or a peach.

The style or stigma sometimes remains as an important part of the fruit in the shape of a hook, as in the common hooked crowfoot; or in the shape of a plumed appendage, as in the virgin's bower, often called wild hops. The calyx may develop hooks, as in the agrimony, or plumes, as in the thistle, the dandelion, lettuce, and many other familiar plants. In the apple, pear, and very many berries, the calyx becomes enlarged and pulpy, often constituting the main bulk of the mature fruit. The receptacle not infrequently, as in the apple, forms a more or less important part of the fruit.

234. Indehiscent and Dehiscent Fruits. — All of the fruits considered in the next three sections are *indehiscent*,

[1] See Gray's *Structural Botany*, Chapter VII, also Kerner and Oliver's *Natural History of Plants*, Vol. II, pp. 427–438.

that is, they remain closed after ripening. *Dehiscent* fruits when ripe open in order to discharge their seeds. The three classes which immediately follow Sect. 237 belong to this division.

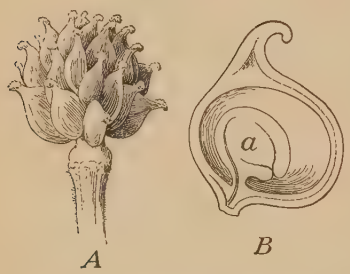


FIG. 166. — Akenes of a Buttercup. *A*, head of akenes ; *B*, section of a single akene (magnified) ; *a*, seed.

235. The Akene. — The one-celled and one-seeded pistils of the buttercup, strawberry, and many other flowers, ripen into a little fruit called an *akene* (Fig. 166). Such fruits, from their small size, their dry consistency, and the fact that they never open, are usually taken for seeds by those who are not botanists.

In the group of plants to which the daisy, the sunflower, and the dandelion belong, the akenes consist of the ovary and the adherent calyx tube. The limb of the calyx is borne on the summit of many akenes, sometimes in the form of teeth, sometimes as a tuft of hairs or bristles (Fig. 267).

236. The Grain. — Grains, such as corn, wheat, oats, barley, rice, and so on, have the interior of the ovary completely filled by the seed, and the seed-coats and the wall of the ovary are firmly united, as shown in Fig. 6.

FIG. 167. — Chestnuts.

237. The Nut. — A nut (Fig. 167) is larger than an akene, usually has a harder shell, and commonly contains

a seed which springs from a single ovule of one cell of a compound ovary, which develops at the expense of all the other ovules. The chestnut-bur is a kind of involucre, and so is the acorn-cup. The name *nut* is often incorrectly applied in popular language; for example, the so-called Brazil-nut is really a large seed with a very hard testa.

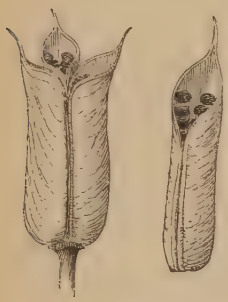


FIG. 168. — Group of Follicles and a Single Follicle of the Monkshood.

238. The Follicle. — One-celled, simple pistils, like those of the marsh marigold, the columbine, and a good many other plants, often produce a fruit which dehisces along a single suture, usually the ventral one. Such a fruit is called a *follicle* (Fig. 168).

239. The Legume. — A legume is a one-celled pod, formed by the maturing of a simple pistil, which dehisces along both of its sutures, as already seen in the case of the bean pod, and illustrated in Fig. 271.

240. The Capsule. — The dehiscent fruit formed by the ripening of a compound pistil is called a *capsule*. Such a fruit may be one-celled, as in the linear pod of the celandine (Fig. 271), or several-celled, as in the fruit of the poppy, the morning-glory, and the jimson weed (Fig. 271).

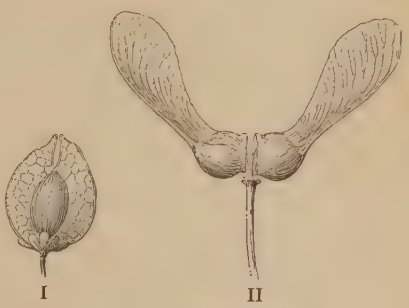


FIG. 169. — Winged Fruits. I, elm; II, maple.

241. Dry Fruits and Fleshy Fruits. — In all the cases discussed or described in Sects. 238–240, the wall of the ovary (and the adherent calyx when present) ripen into tissues which are somewhat hard and dry. Often, however, these parts become developed into a juicy or fleshy mass by which the seed is surrounded; hence a general division of fruits into *dry fruits* and *fleshy fruits*.

242. The Stone-Fruit. — In the peach, apricot, plum, and cherry, the *pericarp* or wall of the ovary, during the process of ripening, becomes converted into two kinds of tissue, the outer portion pulpy and edible, the inner portion of almost stony hardness. In common language the hardened inner layer of the pericarp, enclosing the seed, is called the *stone* (Fig. 170), hence the name *stone-fruits*.

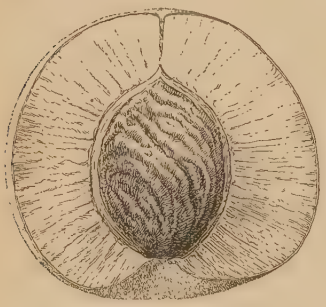


FIG. 170. — Peach. Longitudinal Section of Fruit.

243. The Pome. — The fruit of the apple, pear, and quince is called a *pome*. It consists of a several-celled ovary, — the seeds and the tough membrane surrounding them in the *core*, — enclosed by a fleshy, edible portion which makes up the main bulk of the fruit and is formed from the much-thickened calyx, with sometimes an enlarged receptacle. In the apple and the pear much of the fruit is receptacle.

244. The Pepo or Gourd-Fruit. — In the squash, pumpkin, and cucumber, the ripened ovary, together with the thickened adherent calyx, makes up a peculiar fruit (with a firm outer rind) known as the *pepo*. The relative bulk

of enlarged calyx and of ovary in such fruits is not always the same.

How does the amount of material derived from fleshy and thickened placentæ in the squash compare with that in the watermelon?

245. The Berry. — The berry proper, such as the tomato, grape, persimmon, gooseberry, currant, and so on, consists of a rather thin-skinned, one- to several-celled, *fleshy ovary* and its contents. In the first three cases above mentioned the calyx forms no part of the fruit, but it does in the last two, and in a great number of berries.

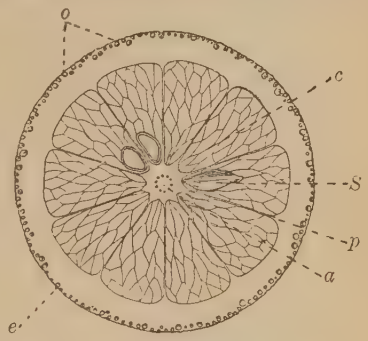


FIG. 171. — Cross-Section of an Orange.
a, axis of fruit with dots showing cut-off ends of fibro-vascular bundles; *p*, partition between cells of ovary; *S*, seed; *c*, cell of ovary, filled with a pulp composed of irregular tubes, full of juice; *o*, oil reservoirs near outer surface of rind; *e*, corky layer of epidermis.

The gourd-fruit and the *hesperidium*, such as the orange (Fig. 171), lemon, and lime, are merely decided modifications of the berry proper.

246. Aggregate Fruits. — The raspberry, blackberry (Fig. 172), and similar fruits consist of many carpels, each of which ripens into a part of a compound mass, which, for a time at least, clings to the receptacle. The whole is called an *aggregate fruit.*

To which one of the preceding classes does each unit of a blackberry or of a raspberry belong?

What is the most important difference in structure between a fully ripened raspberry and a blackberry?

247. Accessory Fruits and Multiple Fruits. — Not infrequently, as in the strawberry (Fig. 172), the main bulk of the so-called fruit consists neither of the ripened ovary nor its appendages. Such a combination is called an *accessory fruit.*

Examine with a magnifying glass the surface of a small, unripe strawberry, then that of a ripe one, and finally a section of a ripe one, and decide where the separate fruits of the strawberry are found, what kind of fruits they are, and of what the main bulk of the strawberry consists.

The fruits of two or more separate flowers may blend into a single mass, which is known as a *multiple fruit.* Perhaps the best-known edible examples of this are the

FIG. 172. — I, Strawberry; II, Raspberry; III, Mulberry.

mulberry (Fig. 172) and the pineapple. The last-named fruit is an excellent instance of the seedless condition which not infrequently results from long-continued cultivation.

248. Summary. — The student may find it easier to retain what knowledge he has gained in regard to fruits if he copies the following synopsis of the classification of fruits, and gives an example of each kind.

- Fruits
  - Composition
    - Simple.
    - Aggregate.
    - Accessory.
    - Multiple.
  - Texture
    - Fleshy
      1.
      2.
      3.
    - Stone
    - Dry
      1.
      2.
      3.
      4.
  - Mode of disseminating seed
    - Indehiscent
      1.
      2.
      3.
    - Dehiscent
      1.
      2.
      3.

CHAPTER XIX

THE CLASSIFICATION OF PLANTS[1]

249. Natural Groups of Plants. — One does not need to be a botanist in order to recognize the fact that plants naturally fall into groups which resemble each other pretty closely, that these groups may be combined into larger ones the members of which are somewhat alike, and so on. For example, all the bulb-forming spring buttercups[2] which grow in a particular field may be so much alike in leaf, flower, and fruit that the differences are hardly worth mentioning. The tall summer buttercups[3] resemble each other closely, but are decidedly different from the bulbous spring-flowering kind, and yet are enough like the latter to be ranked with them as buttercups. The yellow water-buttercups[4] resemble in their flowers the two kinds above mentioned, but differ from them greatly in habit of growth and in foliage, while still another, a very small-flowered kind,[5] might fail to be recognized as a buttercup at all.

The marsh marigold, the hepatica, the rue anemone, and the anemone all have a family resemblance to buttercups,[6] and the various anemones by themselves form another group like that of the buttercups.

[1] See Warming and Potter's *Systematic Botany*, Strasburger, Noll, Schenk, and Karsten's *Text-Book of Botany*, Part II, or Kerner and Oliver, Vol. II, pp. 616–790. [2] *R. bulbosus.* [3] *R. acris.* [4] *R. delphinifolius.* [5] *R. abortivus.* [6] Fresh specimens or herbarium specimens will show this.

250. Genus and Species. — Such a group as that of the buttercups is called a *genus* (plural *genera*), while the various kinds of buttercups of which it is composed are called *species*. The scientific name of a plant is that of the genus followed by that of the species. The generic name begins with a capital; the specific does not, unless it is derived from the name of a person or from the name of a genus. After the name comes the abbreviation for the name of the botanist who is authority for it; thus the common elder is *Sambucus canadensis* L., L. standing for Linnæus. Familiar examples of genera are the Violet genus, the Rose genus, the Oak genus. The number of species in a genus varies greatly, — the Kentucky Coffee-tree genus contains only one species, while the Golden-rod genus comprises more than fifty species in the northeastern United States alone.

251. Hybrids. — If the pollen of a plant of one species is placed on the stigma of a plant of the same genus but a different species, no fertilization will usually occur. In a large number of cases, however, the pistil will be fertilized, and the resulting seed will often produce a plant intermediate between the two parent forms. This process is called *hybridization*, and the resulting plant a *hybrid*. Many hybrid oaks have been found to occur in a state of nature, and hybrid forms of grapes, orchids, and other cultivated plants, are produced by horticulturists at will.

252. Varieties. — Oftentimes it is desirable to describe and give names to subdivisions of species. All the cultivated kinds of apple are reckoned as belonging to one species, but it is convenient to designate such varieties as the

Baldwin, the Bellflower, the Rambo, the Gravenstein, the Northern Spy, and so on. Very commonly varieties do not, as horticulturists say, "come true," that is to say, the seeds of any particular variety of apple not only are not sure to produce that variety, but they are nearly sure to produce a great number of widely different sorts. Varieties which will reproduce themselves from the seed, such as pop-corn, sweet corn, flint-corn, and so on, are called *races*.

Only long and careful study of plants themselves and of the principles of classification will enable any one to decide on the limits of the variety, species, or genus, that is, to determine what plants shall be included in a given group and what ones shall be classed elsewhere.

253. Order or Family. — Genera which resemble each other somewhat closely, like those discussed in Sect. 249, are classed together in one order or family. The particular genera above mentioned, together with a large number of others, combine to make up the Crowfoot family. In determining the classification of plants most points of structure are important, but the characteristics of the flower and fruit outrank others because they are more constant, since they vary less rapidly than the characteristics of roots, stems, and leaves do under changed conditions of soil, climate, or other surrounding circumstances. Mere size or habit of growth has nothing to do with the matter, so the botanist finds no difficulty in recognizing the strawberry plant and the apple tree as members of the same family.

This family affords excellent illustrations of the meaning of the terms *genus*, *species*, and so on. Put in a

tabular form, some of the subdivisions of the Rose family are as follows:

- The Rose family includes (among many others):
  - Plum genus
    - Peach species (many varieties).
    - Garden plum species (many varieties).
    - Wild black cherry species.
    - Garden red cherry species (many varieties).
  - Rose genus
    - Dwarf wild rose species.
    - Sweet-brier species.
    - India rose species
      - Tea variety.
      - Pompon variety, etc.
    - Damask rose species.
  - Pear genus
    - Pear species
      - Seckel variety.
      - Bartlett variety.
      - Sheldon variety, etc.
    - Apple species
      - Baldwin variety.
      - Greening variety.
      - Bellflower variety.
      - Northern Spy variety, etc.

254. Grouping of Families. — Families are assembled into *classes*, and these again into larger *groups*. The details of the entire plan of classification are too complicated for any but professional botanists to master, but an outline of the scheme may be given in small space.

The entire vegetable kingdom is divided into two great divisions, the first consisting of *cryptogams* or spore-plants, the second of *phanerogams* or seed-plants. Here the relations of the various subdivisions may best be shown by a table.[1]

[1] This is, of course, only for consultation, not to be committed to memory.

255. Table of the Classification of the Vegetable Kingdom.

- **Division I — Cryptogams or Spore-Plants**
  - **Group I — Myxothallophytes or *plasmodial plants***
    - Class *Myxogasteres*, Common slime-fungi.
  - **Group II — Thallophytes or *leafless cellular cryptogams*[1]**
    - Class 1. *Schizomycetes*, Bacteria.
    - " 2. *Schizophyceæ*, Fission-plants.
    - " 3. *Bacillariales*, Diatoms.
    - " 4. *Conjugatæ*, Desmids and pond-scums.
    - " 5. *Chlorophyceæ*, Green algæ.
    - " 6. *Phæophyceæ*, Brown algæ.
    - " 7. *Rhodophyceæ*, Red algæ.
    - " 8. *Phycomycetes*, Moulds, etc.
    - " 9. *Basidiomycetes*, Mildews, rusts, and toadstools.
    - " 10. *Ascomycetes*, Yeasts, truffles, etc.
    - Collateral Class. — *Lichenes* — Algæ and fungi leading a life in partnership, the combination known as a *lichen*.
  - **Group III — Bryophytes or *moss-like plants***
    - Class 1. *Hepaticæ*, Liverworts.
    - " 2. *Musci*, True mosses.
  - **Group IV — Pteridophytes or *fern-like plants***
    - Class 1. *Filicales*, Ferns.
    - " 2. *Equisetales*, Scouring rushes.
    - " 3. *Lycopodiales*, Club mosses.

[1] Classes 3–7 inclusive of the thallophytes are often placed in a subgroup known as *algæ*, and 8–10 inclusive in another subgroup, *fungi*.

Division II Phanerogams or Seed-Plants	Class I Gymnosperms or *seed-plants with naked ovaries*, such as pines, spruces, cedars, and many other evergreen trees.	
	Class II Angiosperms or *seed-plants with closed ovaries*	Subclass I Monocotyledonous Plants
		Subclass II Dicotyledonous Plants

256. The Groups of Cryptogams. — The student is not to suppose that the arrangement of cryptogams into the four great groups given in the preceding table is the only way in which they could be classed. It is simply one way of dividing up the enormous number of spore-bearing plants into sections, each designated by marked characteristics of its own. But the amount of difference between one group and another is not always necessarily the same. The pteridophytes and the bryophytes resemble each other much more closely than the latter do the thallophytes, while the myxothallophytes are but little like other plants and it is extremely probable that they are really animals.

The classes given in the table do not embrace all known cryptogams, but only those of which one or more representatives are described or designated for study in this book. Lichens in one sense hardly form a class, but it is most convenient to assemble them under a head by themselves, on account of their extraordinary mode of life, a partnership between algæ and fungi.

257. The Classes of Seed-Plants. — The gymnosperms are much less highly developed than other seed-plants.

The angiosperms constitute the great majority of seed-plants (or, as they have been more commonly called, flowering plants). Only one family of gymnosperms (the *Coniferæ*) is described in Part III of this book, though there are other families of great interest to the botanist, but with no representatives growing wild in the Northern United States.

When people who are not botanists speak of plants they nearly always mean angiosperms. This class is more interesting to people at large than any other, not only on account of the comparatively large size and the conspicuousness of the members of many families, but also on account of the attractiveness of the flowers and fruit of many. Almost all of the book which precedes the present chapter (except Chapter XII) has been occupied with seed-plants.

Seed-plants of both classes frequently offer striking examples of adaptation to the conditions under which they live, and these adaptations have lately received much study, and are now treated as a separate department of botany (see Part II).

CHAPTER XX

TYPES OF CRYPTOGAMS; THALLOPHYTES

258. The Group Thallophytes. — Under this head are classed all the multitude of cryptogams which have a plant-body without true roots, stems, or leaves. Such a plant-body is called a *thallus*. In its simplest form it consists of a portion of protoplasm not enclosed in a cell-wall and without much of any physiological division of labor among its parts (Fig. 125). Only a little less simple are such enclosed cells as that of *Pleurococcus* (Sect. 278) or one of the segments of *Oscillatoria* (Sect. 268). The most complex thallophytes, such as the higher algæ and fungi, have parts definitely set aside for absorption of food and for reproduction. The latter is sometimes accomplished by more than one process and is occasionally aided by some provision for scattering the reproductive bodies or *spores* about when they are mature.

259. Spores. — Before beginning the study of spore-plants it is well for the student to know what a spore is. *A spore is a cell which becomes free and capable of developing into a new plant.* Spores are produced in one of two ways: either *asexually*, from the protoplasm of some part of the plant (often a specialized spore-producing portion), or *sexually*, by the combination of two masses of protoplasm, from two separate plants, or from different parts of the same plant.

Asexually produced spores are sometimes formed, each by the condensation of the protoplasm of a single cell, as shown in Fig. 174, *E*. They are also formed by the contents of spore-cases breaking up into many spores (Fig. 173, *B*; Fig. 210, *D*). Spores are sometimes produced by the spontaneous division of a mass of protoplasm into a small definite number of segments (Fig. 188, *t*). Spores which have the power of moving (swimming) freely are known as *zoöspores* (Fig. 179, *B*).

Sexually produced spores are formed in many ways. One of the simplest modes is that shown in Fig. 178, resulting in *zygospores*. Other methods are illustrated in Figs. 185 and 187.[1]

THE STUDY OF SLIME MOULDS[2]

260. Occurrence. — Slime moulds occur in greenhouses, in tanyards, or on old logs and decaying leaves in woods. They may be cultivated in the laboratory.

They have been described in their vegetative condition on page 179.

261. Examination with the Magnifying Glass. — *Stemonitis* is one of the most available genera to illustrate the fruiting of slime moulds. At maturity the motile protoplasm of the vegetative stage quickly transforms itself into numerous sporangia or spore-cases with dust-like spores. With the naked eye and with a magnifying glass note the color, form, and feathery appearance of the spore-case of *Stemonitis*. The outer wall disappears at an early stage, leaving only an inner structure and spores. Sketch the general outline under a magnifying glass.

262. Examination with the Microscope. — With a low power of the microscope sketch the network of branching hairs which compose the structure of the sporangium. Note the presence or absence

[1] See Vine's *Student's Text-Book of Botany*, pp. 68–71.

[2] This should logically precede Sect. 258.

of a central column. Have any of the branches free tips? With a power of 250 or more examine the spores. A much higher power may be used to advantage. Describe the surface of the spore.

THE STUDY OF BACTERIA

263. Occurrence. — "Bacteria may occur anywhere but not everywhere." In water, air, soil, and almost any organic substance, living

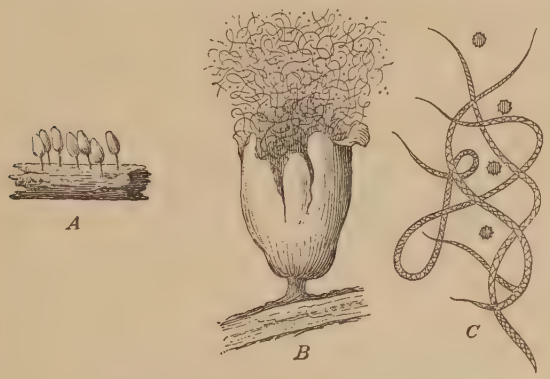


FIG. 173. — Spore-Cases of Slime Moulds.

A, a group of spore-cases of *Arcyria*; *B*, a spore-case of *Trichia*, bursting open and exposing its spores to the wind, × 20; *C*, threads of the same, with spores between them, × 250.

or dead, some species of plant belonging to the group *Bacteria* may occur. A small bunch of hay placed in a tumbler of water will, at a suitable temperature, yield an abundant crop in a few days or hours. Raw peas or beans soaked for a week or two in water in a warm place will afford a plentiful supply.

264. Cultures. — Pure cultures of bacteria are commonly made in some preparation of gelatine in sterilized test-tubes. Boiled potatoes serve a good purpose for simple (but usually not pure) cultures.

Select a few small roundish potatoes with skins entire and boil in water for a sufficient time to cook them through. Cut them in halves with a knife well scalded or *sterilized*, *i.e.*, freed from all living

organisms in a flame, and lay each on a saucer, with cut surface up, covering each with a glass tumbler. The tumblers and saucers should be well scalded or kept in boiling water for half an hour and used without wiping. Sterilization may be improved by baking them in an oven for an hour.

265. Inoculation. — The culture media prepared as above may now be inoculated. Uncover them only when necessary and quickly replace the cover. Scrape a little material from the teeth, tongue, kitchen sink, floor of house or schoolroom, or any other place you may desire to investigate. With the point of a knife blade or a needle sterilized in a flame, inoculate a particle of the material to be cultivated into the surface of one of the potatoes. Several cultures

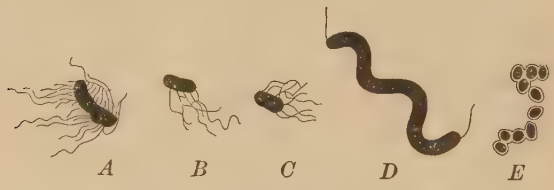


FIG. 174. — Bacteria stained to show Cilia.

A, *Bacillus subtilis*; *B*, *Bacillus typhi* (the bacillus of typhoid fever); *C*, *Bacillus tetani* (the bacillus which causes lockjaw); *D*, *Spirillum undula*; *E*, *Bacillus tetani* forming spores. (All five are magnified 1000 diameters.)

may be made in this way and one or more left uninoculated as checks. Another may be left uncovered in the air for half an hour. Others may be made with uncovered potatoes. Number each culture and keep a numbered record.

Keep watch of the cultures, looking at them daily or oftener. As soon as any change is noticed on the surface of a culture, make a descriptive note of it and continue to record the changes which are seen. Note the color of the areas of growth, their size, outline, elevation above the surface, and any indications of wateriness. Any growth showing peculiar colors or other characters of special interest may be inoculated into freshly prepared culture media, using any additional precautions that are practicable to guard against contamination.

266. Microscopic Examination. — Examine some of the cultures. Place a particle of the growth on a slide, dilute it with a drop of clear water, and place a cover-glass over it. Examine with the highest obtainable power of the microscope, at least $\frac{1}{6}$ in. objective. Note the forms and movements, also the sizes if practicable, of any bacteria that are found.

THE STUDY OF OSCILLATORIA[1]

267. Occurrence. — *Oscillatoria* may occur floating in stagnant water or on damp soil in ditches, roadsides, dooryards, paths, or pots in greenhouses. Other nearly related plants occur on surfaces of ponds sometimes covering considerable areas or adhering in small spheres to submerged vegetation. Algæ of this class are particularly noxious in water supplies, as they partake of the nature of bacteria, to which they are related.

268. Examination with the Microscope. — After washing a particle of *Oscillatoria* material in a drop of water to remove as much of the earth as possible, place it in a clean drop of water, pull to shreds with needles, cover, and examine under a power of 200 or more diameters.

Note the color and compare it with chlorophyll green.

The filament is not one plant, but each of the cells which compose it is one plant. They are packed together in the filament like coins and sometimes may be found separating singly. The usual mode of reproduction is by the separation of a number of adhering cells as a short filament from one end of a longer one, and this increases in length by the dividing of its individual cells.

269. Movement. — At ordinary temperatures, favorable to growth, movement may be observed in the filaments. Describe the movement. What has it to do with the name of the plant?

[1] A genus of the class *Schizophyceæ*.

THE STUDY OF DIATOMS

270. Occurrence. — Diatoms of different species may be found in sediment in water in various kinds of places or mixed with or adhering to fresh-water or marine algæ, in ponds and ditches or on sand or earth at the bottom of clear brooks. In the last place they may be detected with the eye, forming a yellowish coloring. They may often be obtained by straining hydrant water. Where diatoms have been very abundant their remains sometimes form beds of rock, and fossil diatoms compose some of the polishing powders of commerce.

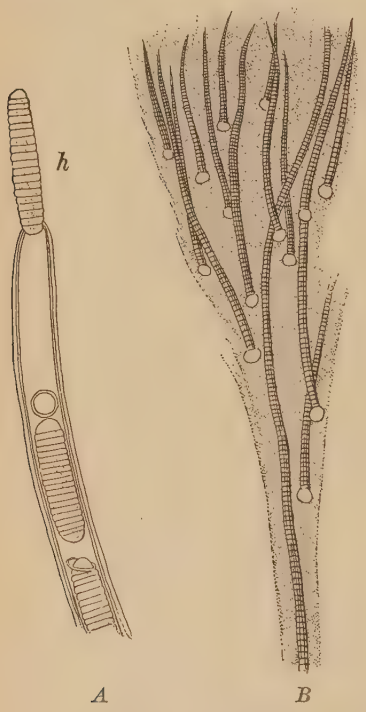


FIG. 175. — *Schizophyceæ.*

A, a filament of *Calothrix*, reproducing by *hormogonia*, *h*, segmented portions which escape from the sheath of the filament; *B*, *Rivularia*. (Both *A* and *B* greatly magnified.)

271. Microscopical Examination of Diatoms. — Place a drop of water containing diatoms on a slide and put a cover-glass over it. Examine with a power of 200 or more diameters. Diatoms occur singly, resembling triangles, wheels, boats, rods, and a great variety of other forms (Fig. 176), or adhering in long bands, as spokes of a wheel, etc. The boat-shaped kinds are among the commonest. The color of the contents is yellowish. The cell-wall is encrusted with a shell of silica whose surface is covered with beautiful markings, dots or lines, which are conspicuous in some species, in others so minute that the most powerful microscopes are required to detect them. By boiling

in nitric acid, the cellulose wall and its contents may be destroyed and the markings of the siliceous shell more easily observed. Each diatom consists of a single cell.

272. Movements of Diatoms. — Living diatoms exhibit a peculiar power of movement. In the boat-shaped species the movement is much like that of a row-boat, forward or backward.

THE STUDY OF SPIROGYRA

273. Occurrence. — *Spirogyra*, one of the plants commonly known as pond-scum, or "frog-spit," occurs widely distributed throughout the country in ponds, springs, and clear streams. It is of a green or yellowish-green color, and in sunny weather usually floats on or near the surface of the water, buoyed up by the numerous oxygen bubbles which it sets free. It may be found flourishing in unfrozen springs, even in midwinter.

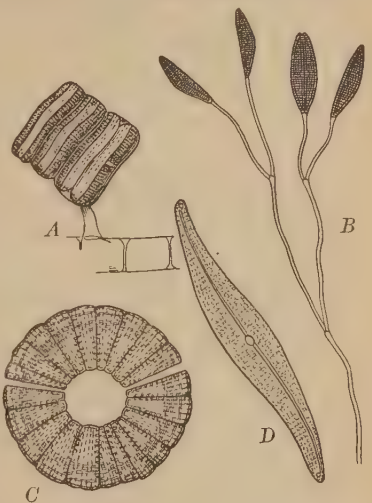


FIG. 176. — A Group of Diatoms.
A, Achnanthes; B, Cocconema; C, Meridion; D, Pleurosigma.

274. Examination with the Magnifying Glass.[1] — Float a little of the material in a white plate, using just water enough to cover the bottom of the latter. Study with the magnifying glass and note the green color of the threads and their great length as compared with their thickness. Are all the filaments about equal to each other in diameter? Handle a mass of the material and describe how it feels between the fingers.

275. Examination with the Microscope. — Mount in water under a large cover-glass and examine first with a power of about 100

[1] Consult Huxley's *Biology* and Spalding's *Introduction to Botany*.

diameters, then with a power of 200 diameters or more. Note the structure of the filaments. Of what is each made up? Compare with the structure of *Oscillatoria*.

Move the slide so as to trace the whole length of several filaments, and, if the unbroken end of one can be found, study and sketch it.

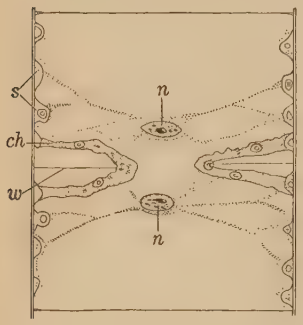


FIG. 177. — Process of Cell-Multiplication in a Species of *Spirogyra*. (× 230.)

The cell at first contained a nucleus near its center. This divided into two portions, the daughter nuclei, one for each half cell.

At *n*, *n* the daughter nuclei are seen on either side of the newly forming partition wall *w*. By its growth the partition pushes inward the band of chlorophyll *ch* which lines the cell-wall. Sections of this band are seen at various points *s*. Threads of protoplasm join it to the nuclei.

Study with the higher power a single cell of one of the larger filaments and ascertain the details of structure. Try to discover, by focusing, the exact shape of the cell. How do you know that the cells are not flat? Count the bands of chlorophyll. The number of bands is an important characteristic in distinguishing one species from another.

Run in five-per-cent salt solution at one edge of the cover-glass (withdrawing water from the other edge with a bit of blotting paper). If any change in the appearance of the cell becomes evident, make a sketch to show it. What has happened to the cell-contents? Explain the cause of the change by reference to what you know of osmosis.

On a freshly mounted slide run under the cover-glass iodine solution, a little at a time, and note its action on the nucleus. Is any starch shown to be present by dark blue coloration? If so, just how is it distributed through the cell?

276. Reproduction of Spirogyra. — The reproductive process in *Spirogyra* is of two kinds, the simplest being a process of *fission*, or cell-division. The nucleus undergoes a very complicated series of transformations, which result in the division of the protoplasmic contents of a cell into two independent portions, each of which is at length surrounded by a complete cell-wall of its own. In Fig. 177

the division of the protoplasm and formation of a partition of cellulose in *Spirogyra* are shown. The stage represented is that following immediately the division of the nucleus.

Another kind of reproduction, namely by *conjugation*, is found in *Spirogyra*. This process in its simplest form is found in such unicellular plants as the desmids (Fig. 178). Two cells (apparently precisely alike) come in contact, undergo a thinning-down or absorptive process in the cell-walls at the point of contact, and finally blend their protoplasmic cell-contents, as shown in the figure, to form a mass known as a *spore*, or more accurately a *zygospore*, from which, after

FIG. 178.—Conjugation of Cells of Green Algæ. (Much magnified.)

I. Conjugation of Desmids. *A*, a single plant in its ordinary condition; *B*, empty cell-wall of another individual; *C*, conjugation of two individuals to form a spore by union of their cell-contents.

II. Conjugation of *Spirogyra*. *A*, two filaments of *Spirogyra* side by side, with the contents of adjacent cells uniting to form spores, *z*. At the bottom of the figure the process is shown as beginning at the top as completed, and the cells of one filament emptied; *B*, a single filament of another kind of *Spirogyra*, containing two spores, one lettered *z*. (*A* magnified 240 diameters, *B* 150 diameters.)

a period of rest, a new individual develops. In *Spirogyra* each cell of the filament appears to be an individual and can conjugate like the one-celled desmids. It is not easy to watch the process, since the spore-formation takes place at night. It is possible,

however, to retard the occurrence of conjugation by leaving the *Spirogyra* filaments in very cold water over night, and in this way the successive steps of the conjugating process may be studied by daylight. In such ways the series of phenomena shown in Fig. 178, II, has been accurately followed. If the student cannot follow these operations under the microscope, he may, at least, by looking over the yellower portions of a mass of *Spirogyra* find threads containing fully formed zygospores, like those shown in *B*, Fig. 178.

THE STUDY OF PLEUROCOCCUS

277. **Occurrence.** — *Pleurococcus* may be found on old fences, roofs, and many similar places, particularly on the bark of the north side of trees. The individual plants cannot be detected by the naked eye, but when grouped in masses they form a powdery green covering over indefinite areas of bark. Plenty are seen where it is moist.

278. **Microscopical Examination of Pleurococcus.** — Scrape a minute quantity of *Pleurococcus* from a specimen on bark, place it in a drop of water on a slide, distributing it slightly in the water, lay on it a cover-glass and examine with a power of 200 or more diameters. Sketch with the *camera lucida* one of the largest cells, some of intermediate size, and one of the smallest, beside several divisions of the stage micrometer.

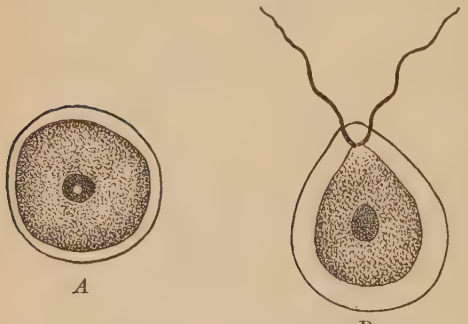


FIG. 179. — Two Cells of *Sphærella*. (Greatly magnified.)

A, a spherical cell of the still form; *B*, a motile cell with its protoplasm enclosed in a loose cell-wall and provided with two cilia.

Note the clearly defined cell-wall of cellulose, enclosing the protoplasmic contents, usually green throughout. Do any cells show a nucleus like that in Fig. 179, *A*?

Test the cells with iodine solution for starch.

Note that in reproduction the cell-contents in many individuals has divided into two parts which become separated from each other by a cellulose partition. Each of these again divides, and the process continues until thirty-two or more cells may be found in one mass or they may fall apart at an earlier stage.

279. Nutrition of Pleurococcus. — *Pleurococcus* can flourish only with an abundance of light and moisture. In daylight it can absorb carbon dioxide and fix carbon (giving off the oxygen at the same time as bubbles of oxygen) and can assimilate mineral substances. It is a capital example of an individual cell capable of independent existence.

280. Motile Forms. — No motile form is known in *Pleurococcus*. *Sphærella*, often known as *Hæmatococcus* (Fig. 179), is a better object for study than *Pleurococcus*. It may sometimes be found in water of stagnant pools, particularly those which contain the drainage of barnyards or manure-heaps, in mud at the bottom of eaves-troughs, in barrels containing rain-water, or in water standing in cavities in logs or stumps. Its presence is indicated by a greenish or sometimes by a reddish color. It is sometimes found in an actively swimming condition, in which case each cell is called a *zoöspore*.

THE STUDY OF VAUCHERIA

281. Occurrence. — Species of *Vaucheria* are found in ponds, streams, and pools, immersed or floating like *Spirogyra* and at all seasons may be sought in greenhouses, where they grow on the moist earth of beds and pots, forming a green felt.

282. Examination with the Magnifying Glass. — The magnifying glass will show the growth of *Vaucheria* to consist of numerous green filaments similar to those of *Spirogyra*. Select a small portion and spread out the filaments carefully in a drop of water on a slide. Does the glass reveal any indications of cross-partitions, of branching, or of fruiting organs as short lateral branches? Does it show the form or arrangement of the green coloring matter?

283. Examination with the Microscope. — Prepare as directed for the magnifying glass and place a cover-glass over the preparation, with sufficient water. With the lowest power observe the

continuity of the cell-cavity and (in young plants growing on soil) search for root-like portions, in those growing in water for branching portions, and fruiting organs in the form of swellings or short lateral branches.

With a power of about thirty to sixty diameters sketch a selected plant of moderate extent as nearly complete as possible or else

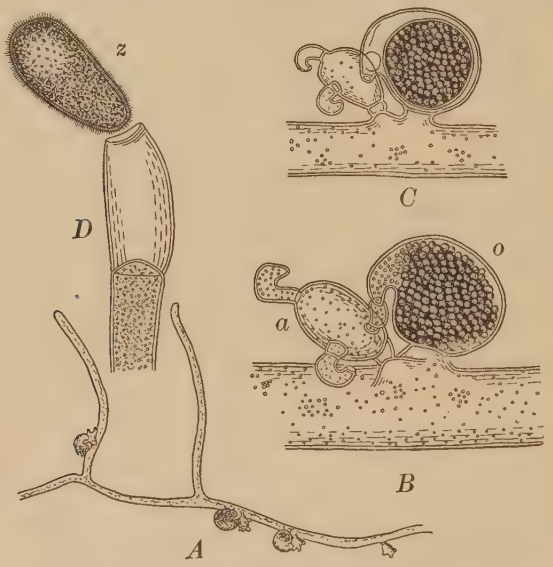


FIG. 180. — *Vaucheria synandra.*

A, a filament with archegonia and antheridia (considerably magnified); *B*, part of same much more highly magnified; *o*, oögonium; *a*, antheridium; *C*, a later stage of *B*; *D*, end of a filament with a zoöspore, *z*, escaping (highly magnified).

sketch a portion showing the branching and a root-like portion. Note and indicate the absence or presence and arrangement of chlorophyll. Can *Vaucheria* probably use carbon dioxide?

284. Reproduction in Vaucheria. — Make an outline sketch of fruiting organs, if found. See if any filaments can be found with the contents massing or escaping at the tips. In some species

zoöspores are formed in this way, having their entire surface clothed with cilia. They are the largest motile cells known. In other species a portion of the filament is separated and cut off by a cell-wall. Such spores soon germinate and may be found in various stages of growth. They often serve for propagation through several generations before spores are produced by fertilization.

With a power of about 200 diameters sketch a portion of a filament to show the form and location of chlorophyll. Sketch the fruiting organs in detail, if any can be found.[1]

Antheridia and oögonia are formed near together on the same filament. The antheridium is a cell forming the terminal portion of a short branch, which is rather slender, straight or curved. Its contents form numerous minute antherozoids, each with two cilia. The cilia can be seen only with great difficulty, if at all, but their presence is indicated by their active movements.

The oögonium is a short, somewhat spheroidal branch separated by a cross-partition at the base. The cell-wall becomes ruptured at the tip, allowing the entrance of the antherozoids by which it is fertilized. After fertilization a cell-wall is formed about the oösphere, and it matures as an oöspore and enters upon a period of rest.

THE STUDY OF NITELLA

285. Occurrence. — *Nitella* is a green plant growing attached to the bottom of ponds and streams, usually in shallow water. It is not common everywhere but is widely distributed. *Chara* is similar and may be used as a substitute but is more complicated.

286. General Aspect. — With the naked eye and a magnifying glass note the general aspect of *Nitella*, the length of the stem-like portions, from the root-like parts to the tip, the length of some of the joints (internodes), the arrangement of leaf-like and branch-like portions.

287. Protoplasm. — Examine the cells of stems or leaves under a low power. Select a vigorous cell of moderate size and examine

[1] Goebel states that the formation of the fruiting organs begins in the evening, is completed the next morning, and that fertilization takes place during the day between ten and four o'clock.

under a power of 200 or more diameters. Select the terminal cell of the leaf if *Chara* is used. The protoplasm is nearly colorless but usually contains bodies which can be seen moving in the current of protoplasm. The protoplasm will show normal activity at the temperature of a comfortable living room. By focusing, see if the current of protoplasm can be detected moving in more than one direction.

FIG. 181. — End of a Main Shoot of *Chara*. (About natural size.)

Note the form and arrangement of the chlorophyll and any places lacking chlorophyll, and see if you can tell whether the arrangement has any relation to the current of protoplasm. With a low power trace the course in several cells. How many cells constitute each internode of *Nitella?* If *Chara* is used, internodes will be found to be covered with a layer of many corticating cells. Under a high power compare the general structure of node and internode and see if the attachment of leaves and branches can be clearly determined. Compare the tip of a leaf with the tip of a stem or branch if the material permits. Are the fruiting organs produced on the stems or the leaves?

288. Antheridia. — The antheridia are globular bodies, bearing male fertilizing cells and becoming red at maturity (Fig. 182). Eight cells compose the outer wall. They have radial lines indicating folds and join one another by irregular sutures. Note a round spot in the middle of each cell which marks the point of attachment within of the stalk on which antherozoid-producing cells are borne.

289. Oögonia. — The egg-shaped fruits, known as *oögonia* (Fig. 182), are borne near the antheridia in monœcious species. Count the number of pointed cells which constitute the "crown" of the fruit. Does each tip consist of one or two short cells? Examine

the surface of the enveloping cells which enclose the spore. What is their number and form? What is their relation to the cells forming the crown? Focus so as to see the large egg-cell (*oösphere* or *oöspore*) which constitutes the center of the fruit. Can you determine anything regarding its contents?

Search for young oögonia and if practicable describe and draw them in several stages of development. Their structure can be seen much more easily than that of the antheridia. Make drawings to illustrate various details of structure.

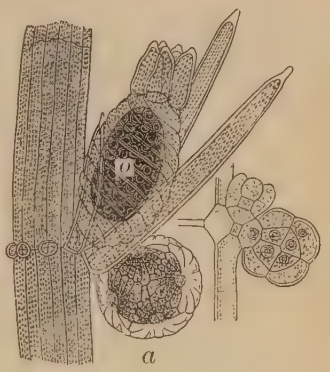


FIG. 182. — Part of a Leaf of Fig. 181. (Considerably magnified.)

a, antheridium; *o*, oögonium. At the right are a young antheridium and archegonium.

290. Characeæ. — *Nitella* and *Chara* are the genera composing the group *Characeæ*, a group of green algæ differing widely from any others. They show in a wonderful manner simplicity of cell-structure with a high degree of organization. Scarcely less wonderful are the care and precision with which botanists have worked out their life history. As a study in evolution the *Characeæ* may be considered as representing the highest development attained along the line of filamentous green algæ, which, while preserving their algal characteristics, are comparable in a remarkable degree with moss- and fern-plants and with seed-plants. Every cell in the plant has been accounted for and is understood in regard to origin, relationship, and function. With harmony of structure throughout, it has organs comparable to root, stem, and leaf in seed-plants, each with characteristic structure and

mode of growth. The stem has nodes and internodes. The stem increases by the growth of an apical cell, but growth in length depends chiefly on the elongation of each internodal cell instead of the multiplication of numerous internodal cells.

THE STUDY OF ROCKWEED[1]

291. Occurrence. — The common rockweed is abundant everywhere on rocks, between high and low tide, on the New England coast and southward.

FIG. 183. — Part of Thallus of a Rockweed (*Fucus platycarpus*), natural size. The two uppermost branchlets are fertile.

292. The Frond. — A plant of rockweed consists mostly of a growth which is somewhat leaf-like, but, in fact, stem and leaf are not separately developed, and the growth is therefore called a *thallus*. This combined stem and leaf has many flat leathery branches which are buoyed up in the water by air-bladders. Cut one of the bladders open and note its form and appearance. Note whether they occur singly or how grouped. Note the prominent midrib running throughout the middle of each branch. Examine the swollen tips of some of the branches and note their peculiarities. Sketch a portion of a frond to show the characteristics so far noted.

293. Reproduction. — Cut across through the middle of one of the swollen fruiting tips. Note the fruiting papillæ (*conceptacles*) as they appear in this section, and make a simple sketch to show their position.

Select some plants with brighter colored tips and some less bright, if any difference

[1] *Fucus vesiculosus* is the most available species. Others may be substituted.

can be detected. After making the microscopic examination which follows, note what correspondence of structure with color has been observed. Cut very thin sections through fruiting tips from different plants, keeping those from each plant separate. Be sure that some of the cuts pass through the conceptacle as near the middle as possible.

Examine with a power of about sixty diameters sections from different fronds, searching for one kind containing rather large egg-shaped cells and another containing bundles of numerous smaller sac-shaped cells. With a power of 200 diameters study the details of the sections. Note the character of the cells forming the surface of the frond, those of the inner structure, and those limiting the cavity of the conceptacle. In a conceptacle cut through the middle note the form of the orifice. Examine the slender hairs or filaments (*paraphyses*) which, arising at right angles, line the walls of the conceptacle.

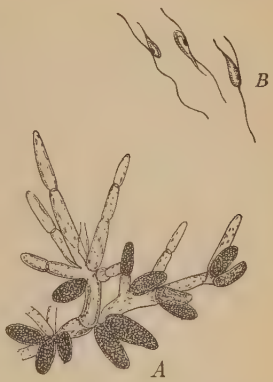
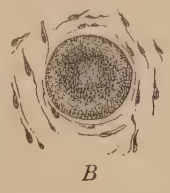


FIG. 184. — Rockweed (*Fucus*). *A*, antheridia borne on branching hairs, × 160; *B*, antherozoids from same, × 330.

294. Oögonia and Antheridia. — In conceptacles containing egg-shaped cells (*oögonia*) note the form, mode of attachment (sessile or stalked), and different stages of development. At maturity the contents are divided, forming eight oöspheres; but not all can be seen at once, some being beneath the others.



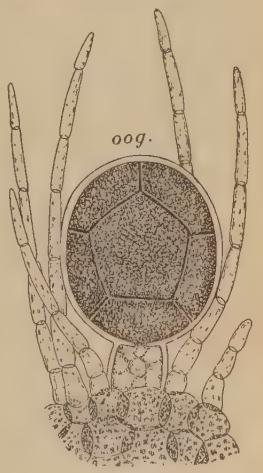


FIG. 185. — Rockweed (*Fucus*). *A*, oögonium, its contents dividing into eight oöspheres, × 160; *B*, an oösphere, escaped, surrounded by antherozoids, × 160.

In conceptacles of the other kind examine the numerous small sac-shaped cells (*antheridia*). At maturity the contents of each divide to form numerous very minute motile *antherozoids*, each with two delicate hairs or cilia. Dissect, by picking and by friction under cover-glass, a bunch of antheridia and note the branching filaments upon which they are borne.

Make drawings to illustrate the various points of structure.

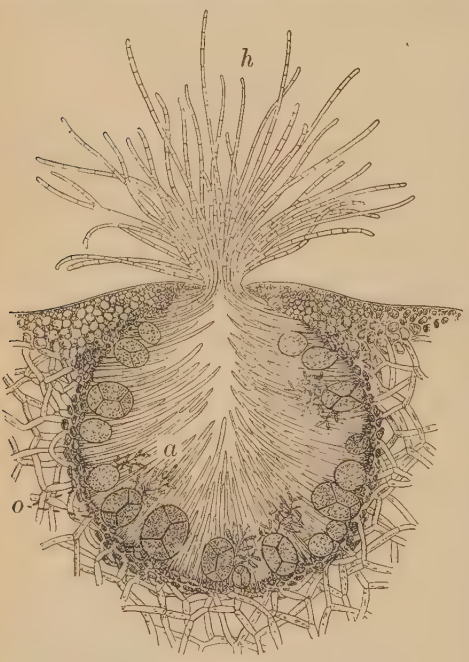


FIG. 186. — Transverse Section of Conceptacle of a Rockweed (*Fucus platycarpus*). (× about 35.)

h, hairs; *a*, antheridia; *o*, oögonia.

295. Number of Antherozoids required for Fertilization. — The bulk of an oösphere has been estimated equal to that of thirty thousand to sixty thousand antherozoids, but apparently an oösphere may be fertilized by only one antherozoid. Yet a large number swarm around each oösphere after both have escaped from the conceptacles, and often their movements are so active as to cause the rotation of the oösphere. The process of fertilization may be discerned in fresh material by squeezing oöspheres and antherozoids from their respective conceptacles into a drop of water on a slide. In some species, as *Fucus platycarpus* (Fig. 186), antheridia and oögonia are found in the same conceptacle.

THE STUDY OF NEMALION

296. Occurrence. — Seven or eight species of *Nemalion* are known in the world, but only one[1] is widely diffused, being found in Europe and on the New England coast from Rhode Island northward. It grows in salt water attached to exposed rocks at low-water mark. *Nemalion* represents the largest of the groups of algæ, nearly all of which live in salt water and have the characteristic color; but a few live in fresh water.

297. Color. — Fresh specimens or those properly dried for the herbarium show the color which is characteristic of the great group to which *Nemalion* belongs. Dried specimens of "Irish moss" (*Chondrus*) and many other species furnish good illustrations. There are many variations of shade and intensity.

Place a piece of a fresh or dried specimen of some species in a beaker of fresh water over night or longer and note the color of the solution and of the treated specimen. Treat another piece similarly with alcohol. A few genera related to *Nemalion* grow in fresh water. What do you infer regarding their color?

298. Form and General Character. — Examine specimens of *Nemalion* and note the size, shape, mode of branching, nature, or consistency of their substance. Examine a fragment of the plant with a power of about sixty diameters and note how the structure differs from what it appears to be to the naked eye. Do cells appear more densely packed or differently colored at any points?

299. Structure. — From a small portion of the plant cut thin longitudinal and transverse sections or pull it to pieces with needles so as to expose the inner portion. Place on a slide under a cover-glass in a drop of water. With a power of about 250 diameters or more examine the general structure of the frond, as shown by a slide prepared as above. Note the central portion (*axis*) of the frond as dissected out, consisting of long, slender, thread-like cells. Examine and draw the branching rows of cells which, radiating from the axis, form the surrounding outer structure of the frond. Note the tips of these branches and look for the fruiting organs and fruit (*spores*).

[1] *Nemalion multifidum.*

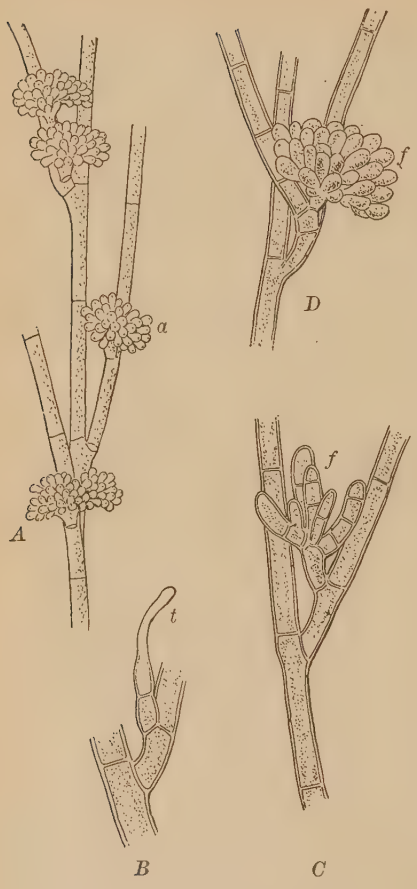


FIG. 187. — Portions of Thallus of a Red Alga (*Chantransia*). (Much magnified.)

A, filaments with antheridia, *a*; *B*, young receptive hair, or *trichogyne*, *t*; *C* and *D*, successive stages in the growth of the clustered fruit, *f*.

300. Organs for Reproduction. — The fruiting organs are to be sought on the radiating branching filaments and are usually produced in great abundance during the summer. Various stages of development may be expected at a given time. The antherozoids are small spheres without cilia, non-motile, with a thin cell-wall. Look for cells in which they are formed (*antheridia*), occurring in groups at the tips of the branches. Compare these with the vegetative cells.

301. Spore-Production. — Look for spore-producing organs in various stages. In the young stage at the time of fertilization, antherozoids, carried by currents of water, may be found adhering. Note the shape of the tip (*trichogyne*) and the base (*carpogonium*), and find whether there is any partition separating them at this stage. Draw or describe a few later stages in development, and note the arrangement of the spores at maturity. Are they naked or enclosed in any sort of envelope? Are they arranged in masses, chains, or otherwise?

302. Other Florideæ. — *Nemalion* represents one of the simplest modes of fruiting in the red algæ. In others there is great variety in structure and great complication in the mode of fruiting. Some species of *Polysiphonia* (or *Dasya*) may well be studied in comparison with *Nemalion* and in further illustration of this important group.[1] Understanding that a siphon, in algæ, is a row of cells, end to end, study the structure of a plant of *Polysiphonia* as illustrating its name. How many siphons are there? Do the main branches have any other cells covering the surface (corticating cells)?

Note the tufts of repeatedly forking, one-siphoned filaments.

303. Fruiting of Polysiphonia. — The antheridia are to be sought on the branching filaments just mentioned. Note how they differ from those of *Nemalion*. The clustered fruits or *cystocarps* will be recognized as ovoid-globose or urn-shaped bodies attached externally to the frond. Note whether the group of spores is naked or otherwise, whether the spores are produced singly or in chains; how attached; shape.

Many *Florideæ* have another kind of fruiting bodies, spores produced without fertilization, coördinate with the asexual spores of black mould (see Sect. 308). In *Florideæ* such spores are usually found in fours and are called *tetraspores*.

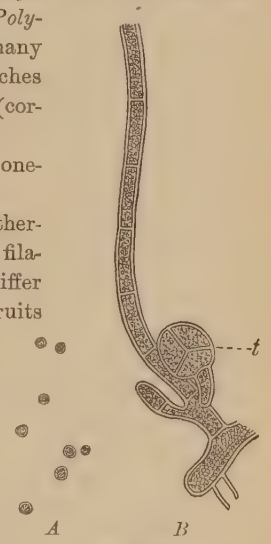


FIG. 188.

A, spores of *Nemalion* (greatly magnified); *B*, portion of thallus of a red alga, *Lejolisia*, with tetraspores, *t*.

Are tetraspores usually found on separate plants?

In *Polysiphonia* the tetraspores appear to be formed in threes (*tripartite*), the fourth being underneath the three. When found, describe their position and arrangement.

304. Algæ. — *Diatom*, *Oscillatoria*, *Pleurococcus*, *Spirogyra*, *Vaucheria*, *Nitella*, *Fucus*, *Nemalion*, these eight

[1] It is desirable also to exhibit fresh or pressed specimens of various genera to show their general aspect.

plants which we have just studied, are types of several families of plants which together make the great group called *Algæ*. Something of its importance in nature is indicated by these facts: The number of known species is about 12,000. In size, the individuals in various species range from a single cell of microscopic dimensions, as in *Pleurococcus*, to the giant kelp of California which reaches a length of more than 1000 feet. The form ranges from a simple spherical cell as in *Pleurococcus* to an extensive, branching cell in *Vaucheria* and its allies, specialized organs in the form of root, stem, leaf, air-bladder, and fruiting organs in *Sargassum*, which is an ally of *Fucus*.

The algæ illustrate a series of modes of propagation from simple division in *Oscillatoria* to the union of two similar masses of protoplasm to form a spore in *Spirogyra*, the direct fertilization of a germ-cell by motile antherozoids in *Vaucheria*, *Nitella*, *Fucus*, the indirect fertilization of fruiting cells by non-motile antherozoids in *Nemalion*. In allies of the latter there are more intricate variations of the same mode.

The algæ fall into five natural groups based primarily on the mode of fruiting. In most cases color is coördinate with class and may be relied upon as a superficial guide in grouping; but there are a few exceptions, *e.g.*, some fruiting like the red group are, nevertheless, green.

The nutrition of the brown and the red algæ is similar to that of the green algæ, since the brown or red color merely conceals the green of the chlorophyll which is present in all and enables them all to take in and decompose carbon dioxide.[1]

[1] See Murray's *Introduction to the Study of Seaweeds*, pp. 4–6. London, 1895.

305. Classification of Types studied.

DIATOMACEÆ. *Diatoms.*	Yellowish.
CYANOPHYCEÆ. *Oscillatoria.*	Blue-green or some similar color.
CHLOROPHYCEÆ. *Pleurococcus, Spirogyra, Vaucheria, Nitella.*	Green.
PHÆOPHYCEÆ. *Fucus.*	Olive.
FLORIDEÆ. *Nemalion.* *Polysiphonia.*	Red.

THE STUDY OF BLACK MOULD (RHIZOPUS NIGRICANS)

306. Occurrence. — This mould may be found in abundance on decaying fruits, such as tomatoes, apples, peaches, grapes, and cherries, or on decaying sweet potatoes or squashes. For class study it may most conveniently be obtained by putting pieces of wet bread on plates for a few days under bell-jars and leaving in a warm place until patches of the mould begin to appear.

307. Examination with the Magnifying Glass. — Study some of the larger and more mature patches and some of the smaller ones. Note:

(*a*) The slender, thread-like network with which the surface of the bread is covered. The threads are known as *hyphæ*, the entire network is called the *mycelium*.

(*b*) The delicate threads which rise at intervals from the mycelium and are terminated by small globular objects. These little spheres are spore-cases. Compare some of the spore-cases with each other and notice what change of color marks their coming to maturity.

308. Examination with the Microscope. — Sketch a portion of the untouched surface of the mould as seen (opaque) with a two-inch objective, then compare with Fig. 189.

Wet a bit of the mould, first with alcohol, then with water. Examine in water with the half-inch objective, and sketch a little of the mycelium, some of the spore-cases, and the thread-like stalks on which they are borne. Are these stalks and the mycelium filaments solid or tubular? Are they one-celled or several-celled?

Mount some of the mature spore-cases in water, examine them with the highest obtainable power, and sketch the escaping spores.

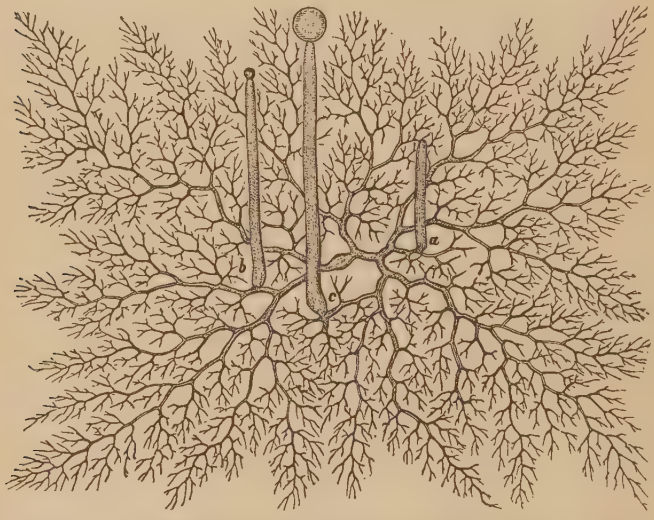


FIG. 189. — Unicellular Mycelium of a Mould (*Mucor Mucedo*), sprung from a Single Spore.

a, *b*, and *c*, branches for the production of spore-cases, showing various stages of maturity. (Considerably magnified.)

Sow some of these spores on the surface of "hay-tea," made by boiling a handful of hay in just water enough to cover it and then straining through cloth or filtering through a paper filter. After from three to six hours examine a drop from the surface of the liquid with a medium power of the microscope (half-inch objective) to see how the development of hyphæ from the spores begins. Sketch.

After about twenty-four hours examine another portion of the mould from the surface of the liquid and study the more fully developed mycelium. Sketch.

309. Zygospores. — Besides the spores just studied, *zygospores* are formed by conjugation of the hyphæ of the black moulds. It is not very easy to find these in process of formation, but the student may be able to gather from Fig. 190 the nature of the process by which they are formed, — a process which cannot fail to remind him of the conjugation of pond-scum.

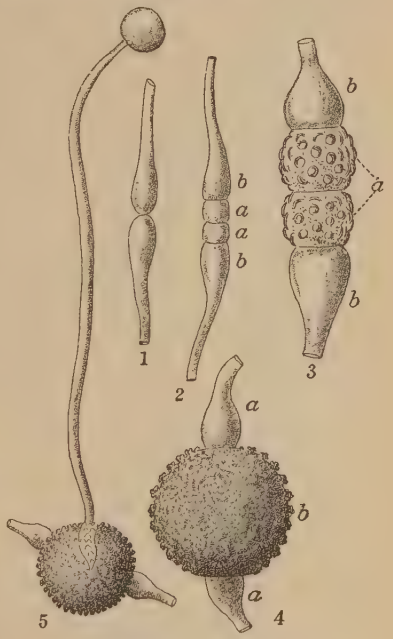


FIG. 190. — Formation of Zygospores in a Mould (*Mucor Mucedo*).

1, threads in contact previous to conjugation; 2, cutting off of the conjugating cells, *a*, from the threads, *b*; 3, a later stage of the process; 4, ripe zygospore; 5, germination of a zygospore and formation of a spore-case. (1–4 magnified 225 diameters, 5 magnified about 60 diameters.)

THE STUDY OF WHEAT RUST (PUCCINIA GRAMINIS)

310. Occurrence. — Wheat rust is common on cultivated wheat and other grains, and also on many wild and cultivated forage grasses. In fact, this or similar rusts occur on a very large number of grasses, and many species of such rusts are recognized. A rust may have one, two, or three kinds of spores, and when three occur one is known as the *cluster-cup stage* and the others as *red rust* and *black rust*, according to the usual approximate color of the spores. The rust called *Puccinia graminis* growing on wheat has its cluster-cup stage on the leaves of barberry in June. The spores from the cluster-cups are carried by the wind to the wheat, where they germinate and in a few days produce the

red rust. A little later the black spores appear, produced from the same mycelium. This growth is chiefly upon the stems and sheaths.

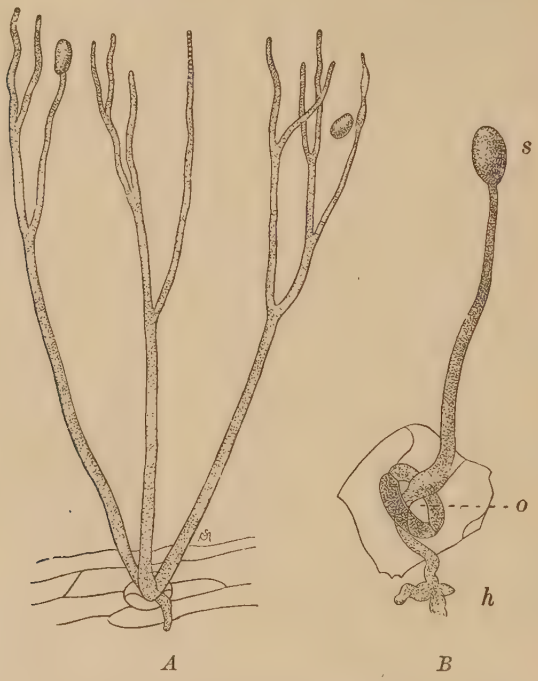


FIG. 191. — Spore-Formation in Potato-Blight (*Phytophthora infestans*).

A, a well-developed group of stalks, proceeding from a mass of mycelium inside the leaf and escaping through a stoma; *B*, a young, unbranched stalk. *h*, hyphæ of mycelium; *o*, stoma; *s*, spore. (Both figures greatly magnified, *B* more than *A*.)

311. Cluster-Cup Stage. — Note with the naked eye and with a magnifying glass the appearance of the cluster-cups upon the barberry leaf. Fresh specimens should be used, if available. Note whether the leaf is changed in form or color in any part occupied by the fungus. Note the number of cups in a cluster, the position on the leaf (which surface?), the form and size, especially the height.

Are they straight or curved? Describe the margin of the cup, the color without, and the color of the contents.

With a power of 200 diameters or more examine some of the cells composing the cup and note the form, color, and nature of the surface. Draw. With the point of a needle or knife pick out a bit of the contents of the cup and examine as above. Note the characters as before and compare in detail with the cells of the cup. The cells within the cup are the spores. Can you tell how they are attached?

A thin section through the cup will show the mode of attachment and the relation of the spores to the cup.

312. Examination of Red and Black Rust. — Under the magnifying glass examine the eruptions of spores (*sori*) on the wheat plant, some of red spores and some of black spores. The red spores are faded in dried specimens. Note the approximate size and shape and any other peculiarities. Prepare slides of each kind of spores and see if both can be found in one sorus. The spores may be taken from the host-plant on the point of a knife by picking rather deeply down into the sorus. Place the small quantity of spores so

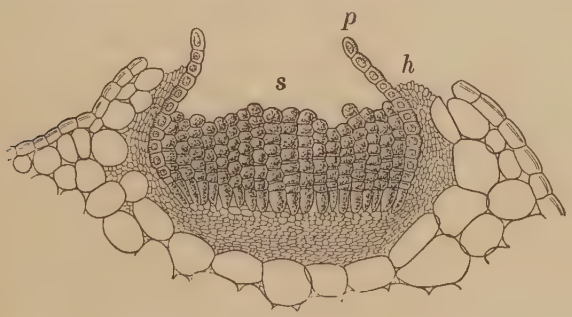


FIG. 192. — A Cluster-Cup of Anemone Rust (*Puccinia fusca*). (× 120.)
s, chains of spores; *p*, the covering or peridium of the cup; *h*, hyphæ.

obtained in a drop of water on a slide, spread with dissecting needles and cover. Examine under a power of 200 or more diameters.

The red spores (*uredospores*) have each a stalk from which they easily fall. They may be seen attached to their stalks if properly

prepared cross-sections through the sorus are available, especially if the material is fresh. Examine the spores and note the shape, color, and surface. If the spores are shrunken, a drop of potash solution will restore the natural plumpness. Draw. Spore-measurements are important in determining species. The *uredospores* of *Puccinia graminis* may be distinguished from those of other species common on grasses by the greater proportionate length.

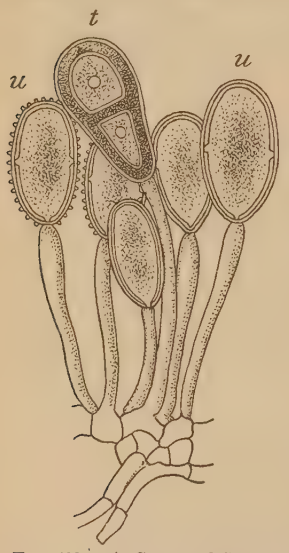


FIG. 193.—A Group of Spores of Wheat Rust (*Puccinia graminis*). (× about 440.)
u, *u*, uredospores; *t*, a teleutospore.

The structure of the black spores (*teleutospores*) can be made out without difficulty. Some should be found attached at the base. Note the parts and the differences in color in different portions. Make careful drawings to show shape and structure of both kinds of spores.

Boil a portion of a rust-injured plant in potash solution, pick it to pieces on a slide under the magnifier or dissecting microscope, use a cover-glass and examine the preparation for mycelium, using a high power.

313. Cultivation on a Host-Plant. — If practicable, find some wheat or grass which has remained over winter with the black rust upon it. Tie a bunch of this to a barberry bush while the leaves are young or unexpanded. When the time arrives for the appearance of the cluster-cups, note whether they are any more abundant on this bush than on others. Are you sure that the rust you have is the one to which the barberry cluster-cups belong?

THE STUDY OF MICROSPHÆRA

314. Occurrence. — Species of *Microsphæra* and allied forms occur in late summer and fall on leaves of various herbaceous and woody plants. The growth is confined to the surfaces of the leaf (upper, lower, or both). Among the most available species are those which grow upon lilac, oak, grape, cherry, willow, and wild plants of the sunflower family. Some species are known to occur on only one host-plant, others occur on several or a large number, and the host-plants may belong to one or more than one family.

Besides *Microsphæra* there are about five other genera, any of which may be substituted or studied comparatively. They are distinguished by the form of the appendages, together with the number of spore-sacs (*asci*) in each sac-receptacle or *perithecium*.

The species of fungi which *Microsphæra* represents are called *powdery mildews*.

With naked eye and magnifying glass examine the surface of a leaf bearing powdery mildew. Note which surface and what portion of the surface is occupied by the fungus, whether the occupied area is restricted or not, the color, and any other characters.

315. Examination with the Microscope. — Place a small drop of water on the leaf where the fungus occurs, if possible where dark-colored specks occur among the mycelium. Pick from the leaf a portion of the fungus loosened by the water and place with a drop of water on a slide. Place a cover-glass over it. Examine under a power of about fifty diameters. The dark-colored specks will be seen as somewhat spherical bodies (*perithecia*). Note their structure and color and their appendages. Have the perithecia any regular way of opening? Note the length of the appendages as compared with the diameter of the perithecia; also note the form of the tips and of the base, the color and any variation of color in different parts of the appendages. Keep the left hand on the focusing screw, and with the needle in the right hand press with gentle but varying stress upon the cover-glass to rupture the perithecia. Even with great care broken cover-glasses may result, but this pressure should force out the contents of the perithecia. Another method is to remove the slide from the microscope and, with a pencil rubber

applied to the cover-glass, rupture the perithecia by gentle grinding between the cover and slide. Note the number and form of the spore-sacs (*asci*) expelled from each of several perithecia. Examine under a power of about 200 diameters and count the number of spores in the asci. Gentle pressure may make them more distinctly visible. Make drawings to illustrate the structural characters observed.

FIG. 194. — A Mushroom (*Armillaria mellea*).

my, mycelium; *c*, *c′*, *c″*, young "buttons"; *st*, stipe or stalk; *r*, ring; *g*, gills.

THE STUDY OF AGARICUS

316. Occurrence. — The common mushroom, *Psalliota* or *Agaricus campestris*, grows in open fields in the United States and Europe. It is the mushroom most extensively cultivated for market, and if not found in the field it may be raised from "spawn" (*mycelium*), put up in the shape of bricks, and sold by seedsmen in the large cities. Those who make a specialty of selling it furnish directions for culture free. A moderately warm cellar or basement makes an excellent winter garden for mushrooms.

317. Structure of Mycelium. — Examine some of the spawn, or mycelium, with the magnifying glass and the low power of the microscope, and with a power of 200 diameters or more examine the individual hyphæ which compose it. Are the hyphæ united in cord-like strands or otherwise, or are they entirely separate? Look for cross-partitions in the hyphæ. Is there any peculiar structure to be found at these places? Are the cross-partitions near together or widely separated?

318. The Spore-Plant. — Search for indications of fruiting, and note the appearance of the "button mushrooms" in all available stages. Draw. See if at any stage up to maturity an outer envelope of tissue (*volva*) can be found enclosing the entire fruiting body. If such be present, what becomes of it at maturity? If material is available, compare the species of *Amanita* (poisonous) in regard to this.

Examine specimens in which the cap is expanding and see if there is another tissue forming a *veil* covering the under surface of the cap. If such be present, how is it attached and what becomes of it?

Take a fresh, well-expanded mushroom or toadstool. Remove the stalk, or *stipe*, close under the cap, or *pileus*, and lay the latter, gills down, on a piece of paper. Let it remain undisturbed for a few hours, or over night, so that the spores may fall upon the paper. Note carefully their color, also the form in which they are arranged on the paper. What determines this form? Examine some of the spores under the highest available power of the microscope. Measure and draw.

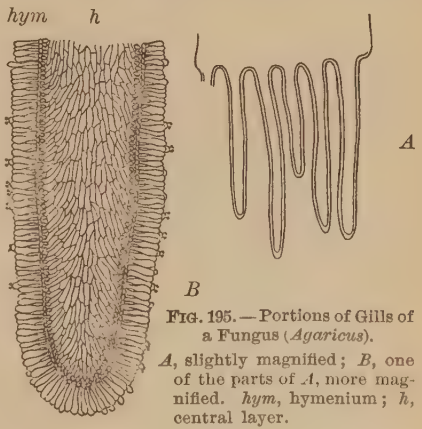


FIG. 195. — Portions of Gills of a Fungus (*Agaricus*).

A, slightly magnified; *B*, one of the parts of *A*, more magnified. *hym*, hymenium; *h*, central layer.

Describe the stipe. Is it a hollow tube or solid? Does it taper? Note length, diameter, color.

Describe the cap, or pileus, in regard to diameter, thickness, nature and color of the upper surface, also color below.

Examine the plates, or *gills*, which compose the under portion of the pileus. Cut a complete pileus and stipe, through the center, and draw an outline to show the shape, noting particularly how the gills are attached. What is the color of the gills?

319. Origin of Spores. — Make a cross-section of one of the gills, and with a magnifying power of about 200 diameters examine the

fruiting cells (*basidia*) which project at right angles to the gill and bear the spores. At how many points (*sterigmata*) on each basidium are spores attached? Draw a basidium, preferably one from which the spores have not yet fallen.

THE STUDY OF YEAST (SACCHAROMYCES CEREVISIÆ)

320. Growth of Yeast in Dilute Syrup. — Mix about an eighth of a cake of compressed yeast with about a teaspoonful of water and stir until a smooth, thin mixture is formed. Add this to about half a pint of water in which a tablespoonful of molasses has been dissolved. Place this mixture in a wide-mouthed bottle which holds one or one and a half pints, stopper *very loosely*[1] and set aside for from twelve to twenty-four hours in a place in which the temperature will be from 70 to 90 degrees. Watch the liquid meantime and note:

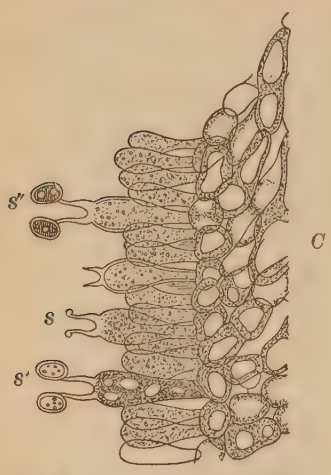


FIG. 196. — Part of the Preceding Figure. (× about 300.)

C, layer of cells immediately under the hymenium; *s*, *s′*, *s″*, three successive stages in growth of spores.

(*a*) The rise of bubbles of gas in the liquid.

(*b*) The increasing muddiness of the liquid, a considerable sediment usually collecting at the end of the time mentioned.

(*c*) The effect of cooling off the contents of the bottle by immersing it in broken ice if convenient, or, if this is not practicable, by standing it for half an hour in a pail of the coldest water obtainable, or leaving it for an hour in a refrigerator, afterwards warming the liquid again.

(*d*) The effect of shutting out light from the contents of the bottle by covering it with a tight box or large tin can.

[1] If the cork is crowded into the neck with any considerable force, pressure of gas and an explosion may result.

(*e*) The result of filling a test-tube or a very small bottle with some of the syrup-and-yeast mixture, from which gas-bubbles are freely rising, and immersing the small bottle up to the top of the neck for fifteen minutes in boiling water. Allow this bottle to stand in a warm place for some hours after the exposure to hot water. What has happened to the yeast-plants?

(*f*) The behavior of a lighted match lowered into the air space above the liquid in the large bottle, after the latter has been standing undisturbed in a warm place for an hour or more.

(*g*) The smell of the liquid and its taste.

321. Microscopical Examination of the Sediment.[1] — Using a very slender glass tube as a pipette, take up a drop or two of the liquid and the upper layer of the sediment and place on a glass slide, cover with a very thin cover-glass and examine with the highest power that the microscope affords.

Note:

(*a*) The general shape of the cells.

(*b*) Their granular contents.

(*c*) The clear spot, or vacuole, seen in many of the cells.

Sketch some of the groups and compare the sketches with Fig. 197.

Run in a little iodine solution under one edge of the cover-glass, at the same time touching a bit of blotting paper to the opposite edge, and notice the color of the stained cells. Do they contain starch?

Place some vigorously growing yeast on a slide under a cover-glass and run in a little eosin solution or magenta solution. Note the proportion of cells which stain at first and the time required for others to stain. Repeat with yeast which has been placed in a slender test-tube and held for two or three minutes in a cup of boiling water.

With a very small cover-glass, not more than three-eighths of an inch in diameter, it may be found possible by laying a few bits of blotting paper or cardboard on the cover-glass and pressing it against the slide to burst some of the stained cells and thus show their thin, colorless *cell-walls* and their semi-fluid contents, *protoplasm*, nearly colorless in its natural condition but now stained by the iodine.

[1] See Huxley and Martin's *Biology*, under *Torula*.

EXPERIMENT XXXIX

Can Yeast grow in Pure Water or in Pure Syrup? — Put a bit of compressed yeast of about the size of a grain of wheat in about four fluid ounces of distilled water, and another bit of about the same size in four fluid ounces of 10 per cent solution of rock candy in distilled water; place both preparations in a warm place, allow to remain for twenty-four hours, and examine for evidence of the growth of the yeast added to each.

322. Size, Form, and Structure of the Yeast-Cell. — The student has discovered by his own observations with the microscope that the yeast-cell is a very minute object, — much smaller than most of the vegetable cells which he has hitherto examined. The average diameter of a yeast-cell is about $\frac{1}{3000}$ of an inch, but they vary greatly both ways from the average size.

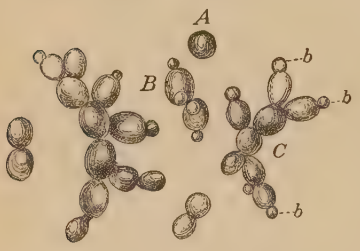


FIG. 197. — Yeast (*Saccharomyces ellipsoideus*) budding actively.

A, a single cell; *B*, group of two budding cells; *C*, a large group; *b*, buds.

The general form of most of the cells of ordinary yeast is somewhat egg-shaped. The structure is extremely simple, consisting of a thin cell-wall, which is wholly destitute of markings, and a more or less granular semi-fluid protoplasm, sometimes containing a portion of clearer liquid, the *vacuole*, well shown in the larger cells of Fig. 197.[1]

323. Substances which compose the Yeast-Cell. — The cell-wall is composed mostly of *cellulose;* the protoplasm consists largely of water, together with considerable portions of a proteid substance,[2]

[1] This is not the ordinary commercial yeast.

[2] It may be found troublesome to apply tests to the yeast-cell on the slide, under the cover-glass. Testing a yeast cake is not of much value, unless it may be assumed that compressed yeast contains little foreign matter and consists mostly of yeast-cells. Still the test is worth making. Millon's reagent does not work well, but the red or maroon color which constitutes a good test for proteids is readily obtained by mixing a teaspoonful of granulated sugar with enough strong sulphuric acid to barely moisten the sugar throughout, and then, as quickly as possible, mixing a bit of yeast cake with the acid and

some fat, and very minute portions of *sulphur*, *phosphorus*, *potash*, *magnesia*, and *lime*. It is destitute of chlorophyll, as would be inferred from its lack of green color, and contains no starch.

324. Food of the Yeast-Cell; Fermentation. — The diluted molasses in which the yeast was grown in Exp. XXXIX contained all the mineral substances mentioned in Sect. 323, together with sugar, proteid materials, and water. The addition of a little nitrate of ammonium would probably have aided the growth of the yeast in this experiment, by supplying more abundantly the elements out of which the yeast constructs its proteid cell-contents. A great deal of sugar disappears during the growth of the yeast.[1] Most of the sugar destroyed is changed into carbon dioxide (which the student saw rising through the liquid in bubbles) and alcohol, which can be separated from the liquid by simple means. The process of breaking up weak syrup into carbon dioxide and alcohol by aid of yeast is one kind of *fermentation;* it is of great practical importance in bread-making and in the manufacture of alcohol. Since grape juice, sweet cider, molasses and water, and similar liquids, when merely exposed to the air soon begin to ferment and are then found to contain growing yeast, it is concluded that dried yeast-cells, in the form of dust, must be everywhere present in ordinary air.

325. Yeast a Plant; a Saprophyte. — The yeast-cell is known to be a plant, and not an animal, from the fact of its producing a coating of cellulose around its protoplasmic contents and from the fact that it can produce proteids out of substances from which animals could not produce them.[2]

On the other hand, yeast cannot live wholly on carbon dioxide, nitrates, water, and other mineral substances, as ordinary green plants can. It gives off no oxygen, but only carbonic acid gas, and is therefore to be classed with the *saprophytes*, like the Indian pipe, among flowering plants (Sect. 180).

sugar. A comparative experiment may be made at the same time with some other familiar proteid substance, *e.g.*, wheat-germ meal.

[1] The sugar contained in molasses is partly cane sugar and partly grape sugar. Only the latter is detected by the addition of Fehling's solution. Both kinds are destroyed during the process of fermentation.

[2] For example, tartrate of ammonia.

326. Multiplication of Yeast. — It is worth while to notice the fact that yeast is one of the few cryptogams which have for ages been largely cultivated for economic purposes. Very recently yeast producing has become a definite art, and the cakes of compressed yeast so commonly sold afford only one instance of the success that has been attained in this process. While yeast-cells are under favorable conditions for growth, they multiply with very great rapidity. Little protrusions are formed at some portion of the cell-wall, as the thumb of a mitten might be formed by a gradual outgrowth from the main portion. Soon a partition of cellulose is constructed, which shuts off the newly formed outgrowth, making it into a separate cell, and this in turn may give rise to others, while meantime the original cell may have thrown out other offshoots. The whole process is called *reproduction by budding*. It is often possible to trace at a glance the history of a group of cells, the oldest and largest cell being somewhere near the middle of the group and the youngest and smallest members being situated around the outside. Less frequently the mode of reproduction is by means of *spores*, new cells (usually four in number), formed inside one of the older cells (*ascus*). At length the old cell-wall bursts, and the spores are set free, to begin an independent existence of their own.

In examining the yeast-cell the student has been making the acquaintance of plant life reduced almost to its lowest terms. The very simplest plants consist, like the slime moulds, of a speck of jelly-like protoplasm. Yeast is more complex, from the fact that its protoplasm is surrounded by an envelope of cellulose, the cell-wall.

THE STUDY OF PHYSCIA

327. Occurrence. — *Physcia* is one of the commonest lichens. It grows attached to the bark of various trees.

328. The Thallus. — *Physcia* consists chiefly of an irregularly expanded growth somewhat leaf-like in texture. It is best to be wet for study. Is it separable from the bark to which it is attached or is it combined with it (incrusted)? Describe the general outline of the margin, the general color, and any special variations of color above, also below. How is the thallus attached to the bark?

329. The Fruit. — Look for small lance-shaped disks seated upon the thallus. Note the approximate sizes and color within and without. These disks are called *apothecia*. Note the very minute black specks (*spermogones*) which are scattered in the surface of the thallus. Pick one from the thallus, with as little of the thallus as possible, and examine under high power. It may be macerated in a drop of potash solution and crushed under the cover-glass. If the contents are not easily defined, they may then be made more opaque by a drop of acetic acid or a stain. The minute colorless bodies contained in the spermogones are

FIG. 198. — A Lichen (*Xanthoria*). (Natural size.)

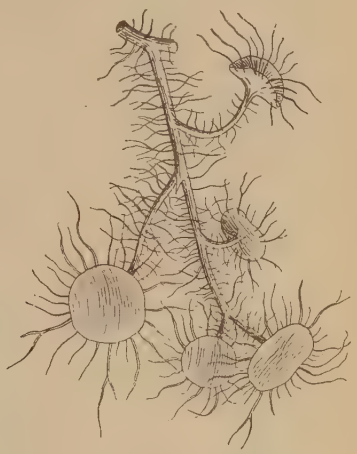


FIG. 199. — A Lichen (*Usnea*). (Natural size.)

called *spermatia*. Their office in *Physcia* is obscure, but in a few lichens they are thought to unite with a trichogyne cell, as in the red algæ.[1] Note the minute, powdery masses (*soredia*) on the surface of the thallus. Macerate if necessary under the cover-glass and examine under a high power. Compare with the structure of the thallus as seen in cross-section. (See next paragraph.) These soredia easily become detached and develop into new plants.

Prepare for sectioning by imbedding a small portion of the thallus with an apothecium in a piece of pith or by any suitable device for sectioning, and cut thin sections of thallus and fruit.

[1] This, however, is doubtful. See Strasburger, Noll, Schenk, and Karsten's *Text-Book of Botany*, pp. 419, 420.

330. Examination of the Thallus. — The thallus of *Physcia* as seen in cross-section will be found to consist of four layers, the upper cortical, gonidial, medullary, and the lower cortical. The cortical layers will be seen to serve for protection, answering the purpose of an epidermis or bark. The cells which compose them make what is called a *false parenchyma*, — resembling parenchyma in form but as to origin being transformed fungal hyphæ. Note the form of the hyphæ composing the medullary layer. Are there any cross-partitions? Do any cells appear circular, and if so, what is the explanation? The upper portion of the cortical layer, having green cells intermixed, constitutes the gonidial layer. Why should the green cells be at the upper part of the medullary layer? Can you detect any connection between the green cells and the hyphæ? Do these green cells resemble any cells previously studied?

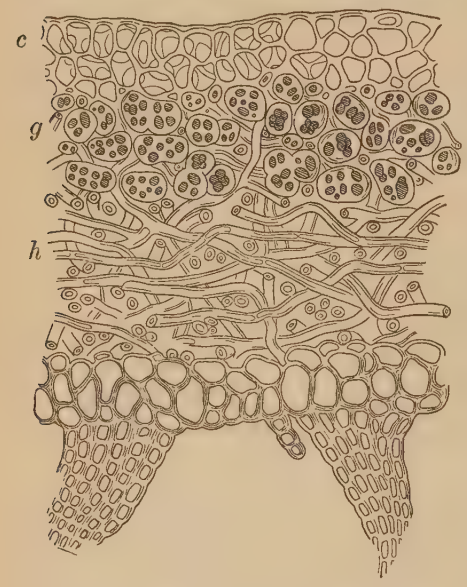


FIG. 200. — Transverse Section through Thallus of a Lichen (*Sticta fuliginosa*). (× 500.)

c, cortical or epidermal layer; *g*, gonidia; *h*, hyphæ.

Make a diagram to show the structure of the thallus.

What arrangement of layers would you expect to find in a lichen thallus, upright or suspended? Compare the arrangement in the fruit-body (*apothecium*), describe, and sketch. How does the layer of cells beneath the spore-sacs resemble the cortical layer? All but these two layers may be considered as part of the thallus. To make out the details of the fruit, the section must be very thin.

Examine the spore-sacs (*asci*) and look for spores in different stages of formation. How many spores are found in each ascus? What other bodies occur among the asci? Draw these, also asci and spores.

331. Lichens. — Lichens were formerly supposed to be a distinct class of plants, and it is only about thirty years since their real nature began to be understood. A lichen is now known to be a combination of two plants. The green cells, called the *gonidia*, belong to some species of alga, and the remainder, the larger portion of the growth, is a fungus parasitic upon that alga. The groups of lichens correspond in structure to certain groups of fungi, but the genera are sufficiently distinct so that lichens are best considered by themselves for purposes of study and classification.

The relation of the fungus and its algal host is not that of destructive parasitism, but rather a mutual relation (*symbiosis*) in which both fungus and alga may have a vigorous growth. The relationship has been investigated in various ways, and it has been found that, while the alga may grow independent of the fungus, the germinating fungus spores can grow only to a limited extent if deprived of the algal host; but if supplied naturally or artificially with the proper alga they make a normal growth.

The same alga may serve as gonidia to a number of lichens, often of very different form, and while the number of lichens reaches into the thousands, the number of algæ known to serve as gonidia is quite small.

Lichens are widely distributed in all zones but flourish particularly in northern regions where other vegetation is scanty. Some were formerly important as sources of

dyes. "Iceland moss" is a lichen used for food, and a finely branching form, growing in extensive mats on the soil, serves as food for the reindeer and is known as "reindeer moss."

Most lichens grow on the bark of trees, on rocks, or soil where they have little moisture except during rainfall, but some grow where they are constantly wet. Some of the latter are gelatinous. Most of the conspicuous lichens are foliaceous or else have a thallus composed of branching, cylindrical, thread-like portions. But many species, often less conspicuous, are crustaceous, growing as if they formed part of the bark or rock to which they are attached.

332. Fungi. — The yeasts, moulds, rusts, mildews, and mushrooms represent an immense group of plants of which about forty-five thousand species are now known in the world. They range from the very simple to quite complex forms, growing as saprophytes or parasites under a great variety of conditions. Their structure and life history are so varied as to constitute a long series of divisions and subdivisions.[1] Chlorophyll is absent from fungi, and they are destitute of starch, but produce a kind of cellulose which appears to differ chemically from that of other plants. Unable to build up their tissues from carbonic acid gas, water, and other mineral matters, they are to be classed, with animals, as consumers rather than as producers, acting on the whole to diminish rather than to increase the total amount of organic material on the earth.

[1] See Strasburger, Noll, Schenk, and Karsten's *Text-Book of Botany*, pp. 328–421 incl., also Potter and Warming's *Systematic Botany*, p. 1, and Engler's *Syllabus der Pflanzenfamilien*, Berlin, 1907, pp. 25–51.

333. Occurrence and Mode of Life of Fungi. — Among the most important cryptogamous plants are those which, like the bacteria of consumption, of diphtheria, of typhoid fever, or of cholera, produce disease in man or in the lower animals. The subclass which includes these plants is known by the name *Bacteria*. Bacteria are now classed by some as a separate group, lower than fungi. Some of the most notable characteristics of these plants are their extreme minuteness and their extraordinary power of multiplication. Many bacteria are on the whole highly useful to man, as is the case with those which produce decay in the tissues of dead plants or animals, since these substances would, if it were not for the destructive action of the bacteria of putrefaction and fermentation, remain indefinitely after death to cumber the earth and lock up proteid and other food needed by new organisms.

The mushrooms and their allies include about one-fourth of the fungi. Some, such as the "dry-rot" fungus, mistakenly so called, cause great destruction to living and dead tree trunks and timber in economic use. The common mushroom, *Psalliota campestris*, is the most important edible species. Probably five hundred kinds can be eaten, but only a few are good food, and even these contain but little nutriment. Some species are dangerous, and a few are deadly poisons. The puffballs are a small group allied to the mushrooms. Most of them are edible and of good quality.

The mildews (*Microsphæra*, etc.) and the "black-knot" of the plum trees are of a group which likewise includes about one-fourth of the fungi. A considerable number are parasites, injurious to vegetation, while thousands of others grow on dead leaves, twigs, etc.

The "rust" of wheat and the "smut" of corn represent groups numbering only a few hundreds of species, which are very important because they are all parasites on living plants, many on our most important economic plants.

Fig. 191, representing another small group of destructive parasites, shows clearly how a parasitic fungus grows from a spore which has found lodgment in the tissues of a leaf and pushes out stalks through the stomata to distribute its spores.

CHAPTER XXI

TYPES OF CRYPTOGAMS; BRYOPHYTES

334. The Group Bryophytes. — Under this head are classed the liverworts and the mosses. Both of these classes consist of plants a good deal more highly organized than the thallophytes. Bryophytes have no true roots, but they have organs which perform the work of roots. Some of them have leaves (Fig. 206), while others have none (Fig. 201). Fibro-vascular bundles are wanting. The physiological division of labor is carried pretty far among all the bryophytes. They have special apparatus for absorbing water and sometimes for conducting it through the stem; stomata are often present and sometimes highly developed. There are chlorophyll bodies, often arranged in cells extremely well situated for acting

FIG. 201. — Part of Male Thallus of a Liverwort (*Marchantia disjuncta*). (Enlarged.)
mr, male receptacle.

on the carbon dioxide gas which the plant absorbs, that is, arranged about rather large air chambers.

Reproduction is of two kinds, sexual and asexual, and the organs by which it is carried on are complicated and highly organized. An *alternation of generations* occurs, that is, the life history of any species embraces two forms: a *sexual generation*, which produces two kinds of cells that by their union give rise to a new plant; the *asexual generation*, which multiplies freely by means of special cells known as *spores*.

FIG. 202. — Part of Female Thallus of *M. disjuncta*. (Enlarged.)

fr, female receptacle; *c*, cups with gemmæ.

THE STUDY OF MARCHANTIA

335. Occurrence. — *Marchantia* grows on soil or rocks in damp shaded places and is widely distributed.

336. The Thallus. — In general form the thallus bears some resemblance to that of some of the lichens, as *Parmelia*, but is plainly different in color, mode of branching, and internal structure under the microscope. Under the microscope (see below) the individual cells may be compared with those of the medullary layer in *Physcia*.

Note the color and general shape of the thallus and study carefully the mode of branching. The origin of the growing cells is at the tip, but cells so originating afterward multiply more rapidly, so that the tip comes to be in a notch.

Viewing the thallus as an opaque object, note the diamond-shaped network on the upper surface and the dot-like circle in the middle of each diamond.

Examine the under surface for (1) rhizoids and (2) scales.

337. Internal Structure. — Cut thin cross-sections of the thallus in the same way as for *Physcia*, making some pass through the circular dots mentioned above. Examine under a high power and note the different kinds and layers of cells composing the thallus. Note the character of the cells forming the upper and lower surfaces. Describe the cells which are next above those of the lower epidermis, their shape, color of contents, approximate number of horizontal rows. Have they any evident intercellular spaces? Find cells connecting these with the upper epidermis and constituting the network of lines seen on the surface of the thallus. Note the air cavity bounded by these lines and the loose cells which occupy it in part. What is the color of their contents? How are they attached, and how arranged? Can you discover any opening through the epidermis? If so, describe it.

FIG. 203. — Section through Antheridial Receptacle of *Marchantia*. (Magnified.)

a, antheridium.

Make drawings to illustrate the details of structure observed.

338. Gemmæ. — Look for a thallus bearing little green cups formed of its own substance. Describe the contents of the cup. The bodies are called *gemmæ*. They originate by vegetative growth alone and when detached may grow into new plants.

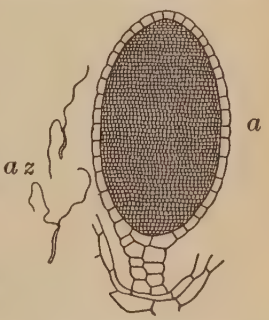


FIG. 204. — Sectional View of an Antheridium of *Marchantia*.

a, antheridium; *az*, antherozoids, × 700.

339. Fruiting Organs. — Look for thalli bearing stalks with umbrella-like expansions. The umbrellas are of two kinds, one disk-like with crenate points (how many?) and the other has rays (how many?) elongated and curving downward. Is there any difference in the height of the two kinds?

Do both occur on the same thallus? On what part of the thallus do they occur, and do they differ in this respect?

340. Antheridia. — The antheridia are formed as outgrowths from the upper surface of the crenate receptacle, but by further growth of the receptacle they become imbedded. They should be examined under a high power and sketched in outline. The antheridium produces numerous motile antherozoids, each with two cilia.

341. Archegonia and Sporophytes. — The receptacle with recurved rays bears the archegonia. Note whether they occur above or below and in what relation to the rays. How are the archegonia protected?

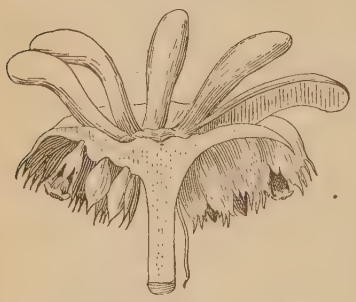


FIG. 205. — Sectional View of Female Receptacle of *Marchantia*. (× 5.)

Note the cells which surround the central canal and form the elongated neck of the archegonium. Does the archegonium open upward or downward? At the base look for the germ-cell.

The antherozoids enter the central canal and penetrating to the egg-cell fertilize it, after which it begins to divide and grows into a sporophyte. In the older specimens, therefore, the sporophytes will be found more or less developed. The archegonium remains upon the tip of the sporophytes. The mature sporophyte contains the spores and also peculiar elongated tapering threads with spiral thickenings. These are called *elaters*.

342. Hepaticæ. — *Marchantia* represents only a small division of the *Hepaticæ*, and is not typical of the larger number of species. In spite of this it is chosen for study, because it is widely distributed and more available for study than most others. In most species the fruit lasts but a little while and good material is hard to obtain. In Marchantia the fruiting organs are abundant, more gradual in their development, and more persistent. Marchantia and

its allies consist chiefly of the thallus in the vegetative condition, while the greater number of Hepaticæ have a stem and leaves. Thus they approach closely to the mosses. But mosses usually have leaves on all sides of the stem, while the leaves of Hepaticæ are two-ranked, spreading laterally, with sometimes a third row of leaves or scales underneath. The leaves of mosses usually have more than one layer of cells in some part, but the leaves of the leafy Hepaticæ have but one layer of cells throughout. The forms of the leaves are often very curious and interesting. The sporophyte of most mosses is a stalked capsule with a lid, while in the leafy Hepaticæ the capsule usually opens by splitting longitudinally into two to four valves.

Different species of Hepaticæ grow on damp soil, rocks, and the bark of trees. Many are capable of enduring drought and reviving with moisture.

THE STUDY OF PIGEON-WHEAT MOSS (*POLYTRICHUM COMMUNE*)

343. Occurrence. — This moss is widely distributed over the surface of the earth, and some of its relatives are among the best known mosses of the northern United States. Here it grows commonly in dry pastures or on hillsides, not usually in densely shaded situations.

344. Form, Size, and General Characters. — Study several specimens which have been pulled up with root-hairs. Note the size, general form, color, and texture of all the parts of the plants examined. Some probably produce spore-bearing plants or *sporophytes* like those shown in Fig. 206, while others are without them. Sketch one plant of each kind, about natural size.

What difference is noticeable between the appearance of the leaves in those plants which have spore-capsules and those which have none? Why is this?

In some specimens the stem may be found, at a height of an inch or more above the roots, to bear a conical, basket-shaped enlargement,

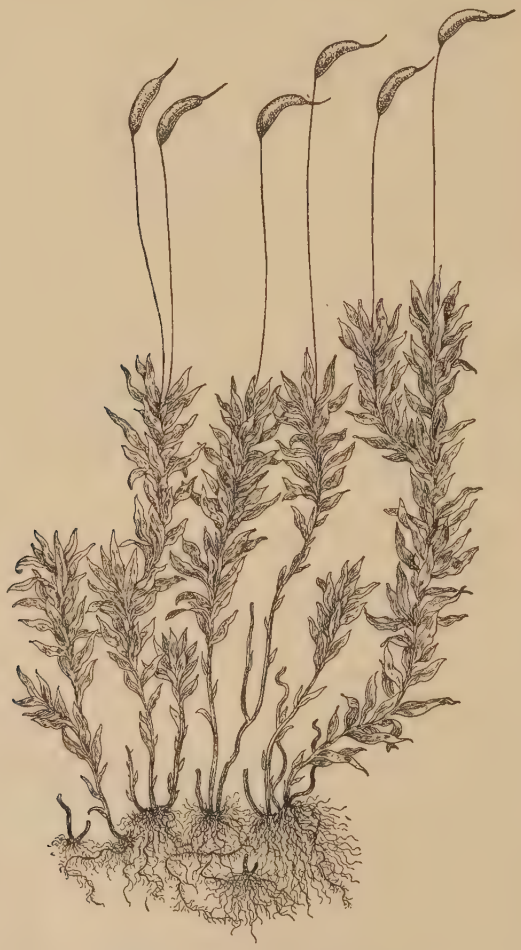


FIG. 206. — A Moss, *Catharinea*.

The sporophytes of this moss are usually rather more slender than as here represented.

out of the center of which a younger portion of the stem seems to proceed; and this younger portion may in turn end in a similar enlargement, from which a still younger part proceeds.

Note the difference in general appearance between the leaves of those plants which have just been removed from the moist collecting-box and those which have been lying for half an hour on the table. Study the leaves in both cases with the magnifying glass in order to find out what has happened to them. Of what use to the plant is this change? Put some of the partially dried leaves in water, in a

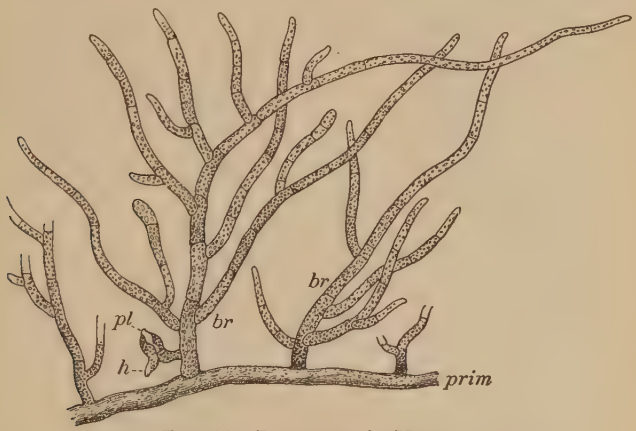


FIG. 207. — Protonema of a Moss.

prim, primary shoot; *h*, a young root-hair; *pl*, young moss-plant; *br*, branches of primary shoot.

cell on a microscope slide, cover, place under the lowest power of the microscope, and examine at intervals of ten or fifteen minutes. Finally sketch a single leaf.

345. Minute Structure of the Leaf and Stem. — The cellular structure of the pigeon-wheat moss is not nearly as simple and convenient for microscopical study as is that of the smaller mosses, many of which have leaves composed, over a large part of their surfaces, of but a single layer of cells, as shown in Fig. 209. If any detailed study of the structure of a moss is to be made, it will, therefore, be better for the student to provide himself with specimens of almost

any of the smaller genera,[1] and work out what he can in regard to their minute anatomy.

FIG. 208. — The Antheridium of a Moss (*Funaria*) and its Contents.

a, antheridium; *b*, escaping antherozoids, × 350; *c*, a single antherozoid of another moss, × 800.

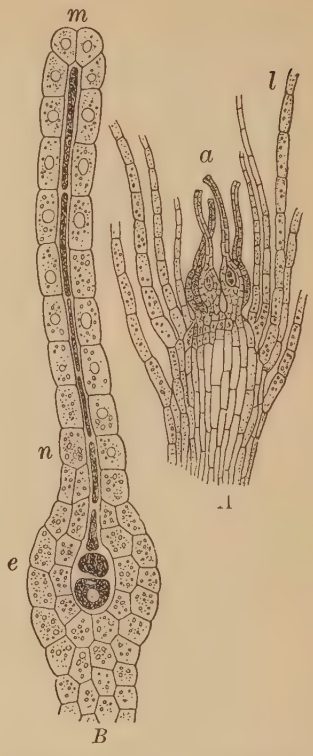


FIG. 209. — Portions of Fertile Plant of a Moss (*Funaria*).

A, longitudinal section of summit of plant, × 100; *a*, archegonia; *l*, leaves; *B*, an archegonium, × 550; *e*, enlarged ventral portion with central cell; *n*, neck; *m*, mouth.

346. Sporophytes. — That part of the reproductive apparatus of a common moss which is most apparent at a glance is the *capsule* of the *sporophyte* (Fig. 206). This is covered, until it reaches maturity, with a hood which is easily detached. Remove the hood from one

[1] As *Mnium* or *Bryum*.

of the capsules, examine with a magnifying glass, and sketch it. Note the character of the material of which its outer layer is composed.

Sketch the uncovered capsule as seen through the magnifying glass, noting the little knob at its base and the circular lid.

Pry off this lid, remove some of the mass of spores from the interior of the capsule, observe their color as seen in bulk through the magnifying glass, then mount in water, examine with the highest obtainable power of the microscope, and sketch them. These spores, if sown on moist earth, will each develop into a slender, branched organism, consisting, like pond-scum, of single rows of cells (Fig. 207) called the *protonema*.

347. Other Reproductive Apparatus. — The student cannot, without spending a good deal of time and making himself expert in the examination of mosses, trace out for himself the whole story of the reproduction of any moss. It is sufficient here to give an outline of the process. The protonema develops buds, one of which is shown in Fig. 207, and the bud grows into an ordinary moss plant. This plant, in the case of the pigeon-wheat moss, bears organs of a somewhat flower-like nature, which contain either *antheridia* (Fig. 208), organs which produce fertilizing cells called *antherozoids*, or *archegonia* (Fig. 209), organs which produce egg-cells, but in this moss antheridia and archegonia are not produced in the same "moss-flower." The plants therefore correspond to dicœcious ones among flowering plants.

After the fertilization of the egg-cell, by the penetration of antherozoids to the bottom of the flask-shaped archegonium, the development of the egg-cell into *sporophyte* begins; the latter rises as a slender stalk, while the upper part of the archegonium is carried with it and persists for a time as the hood or *calyptra*.

CHAPTER XXII

TYPES OF CRYPTOGAMS; PTERIDOPHYTES

348. The Group Pteridophytes. — Under this head are classed the ferns, the scouring-rushes, and the club-mosses. They are the most highly organized of cryptogams, having true roots, and often well-developed stems and leaves.

THE STUDY OF A FERN[1]

349. Conditions of Growth. — If the specimens studied were collected by the class, the collectors should report exactly in regard to the soil and exposure in which the plants were found growing. Do any ferns occur in surroundings decidedly different from these? What kind of treatment do ferns need in house culture?

350. The Underground Portion. — Dig up the entire underground portion of a plant of ladyfern. Note the color, size, shape, and appendages of the rootstock. If any are at hand which were collected in their late winter or early spring condition, examine into the way in which the leafy parts of the coming season originate from the rootstock, and note their peculiar shape (Fig. 210, *A*). This kind of vernation (Sect. 136) is decidedly characteristic of ferns. Observe the number and distribution of the roots along the rootstock. Bring out all these points in a sketch.

[1] The outline here given applies exactly only to *Asplenium filix-fœmina*. Any species of *Asplenium* or of *Aspidium* is just as well adapted for study. *Cystopteris* is excellent, but the indusium is hard to find. *Polypodium vulgare* is a simple and generally accessible form, but has no indusium. *Pteris aquilina* is of world-wide distribution, but differs in habit from most of our ferns. The teacher who wishes to go into detail in regard to the gross anatomy or the histology of ferns as exemplified in *Pteris* will find a careful study of it in Huxley and Martin's *Biology*, or a fully illustrated account in Sedgwick and Wilson's *Biology*.

351. The Frond. — Fern leaves are technically known as *fronds.* Observe how these arise directly from the rootstock.

Make a somewhat reduced drawing of the entire frond, which consists of a slender axis, the *rhachis*, along which are distributed many leaflets or *pinnæ*, each composed of many *pinnules.* Draw the under side of one of the pinnæ, from near the middle of the frond, enlarged to two or three times its natural size, as seen through the magnifying glass. Note just how each pinnule is attached to its secondary rhachis.

Examine the under side of one of the pinnules (viewed as an opaque object without cover-glass) with the lowest power of the microscope, and note:

(*a*) The "fruit-dots" or *sori* (Fig. 210, *B*) (already seen with the magnifying glass, but now much more clearly shown).

(*b*) The membranous covering or *indusium* of each sorus (Fig. 210, *C*). Observe how this is attached to the veins of the pinnule. In such ferns as the common brake (*Pteris*) and the maidenhair (*Adiantum*) there is no separate indusium, but the *sporangia* are covered by the incurved edges of the fronds.

(*c*) The coiled spore-cases or sporangia, lying partly covered by the indusium. How do these sporangia discharge their spores?

Make a drawing, or several drawings, to bring out all these points.

Examine some of the sporangia, dry, with a power of about fifty or seventy-five diameters, and sketch. Scrape off a few sporangia, thus disengaging some spores, mount the latter in water, examine with a power of about 200 diameters, and draw.

352. Life History of the Fern. — When a fern-spore is sown on damp earth it gradually develops into a minute, flattish object, called a *prothallium* (Fig. 211). It is a rather tedious process to grow prothallia from spores, and the easiest way to get them for study is to look for them on the earth or on the damp outer surface of the flower-pots in which ferns are growing in a greenhouse. All stages of germination may readily be found in such localities.

Any prothallia thus obtained for study may be freed from particles of earth by being washed, while held in very small forceps, in a gentle stream of water from a wash-bottle. The student should then mount the prothallium, bottom up, in water in a shallow cell,

FIG. 210.—Spore-Plant of a Fern (*Aspidium Filix-mas*).

A, part of rootstock and fronds, not quite one-sixth natural size; *fr*, young fronds unrolling; *B*, under side of a pinnule, showing sori, *s*; *C*, section through a sorus at right angles to surface of leaf, showing indusium, *i*, and sporangia, *s*; *D*, a sporangium discharging spores. (*B* is not far from natural size. *C* and *D* are considerably magnified.)

cover with a large cover-glass, and examine with the lowest power of the microscope. Note:

(*a*) The abundant root-hairs, springing from the lower surface of the prothallium.

(*b*) The variable thickness of the prothallium, near the edge, consisting of only one layer of cells.

(*c*) (In some mature specimens) the young fern growing from the prothallium, as shown in Fig. 211, *B*.

The student can hardly make out for himself, without much expenditure of time, the structure of the *antheridia* and the *archegonia* (Fig. 211, *A*), by the coöperation of which fertilization takes place on much the same plan as that already described in the case of mosses. The fertilized egg-cell of the archegonium gives rise to the young fern, the *sporophyte* which grows at first at the expense of the parent prothallium but soon develops roots of its own and leads an independent existence.

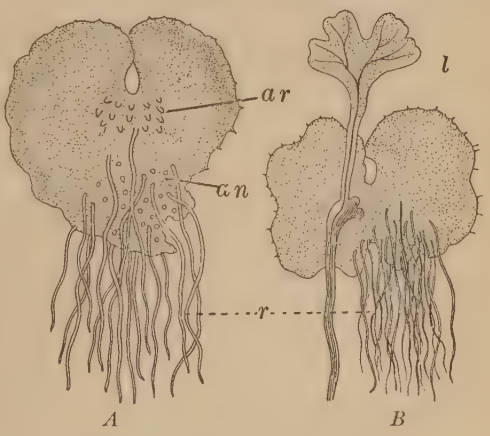


FIG. 211. — Two Prothallia of a Fern (*Aspidium*).
A, under surface of a young prothallium; *ar*, archegonia; *an*, antheridia; *r*, rhizoids; *B*, an older prothallium with a young fern-plant growing from it; *l*, leaf of young fern. (Both × about 8.)

353. Nutrition. — The mature fern makes its living, as flowering plants do, by absorption of nutritive matter from the soil and from the air, and its abundant chlorophyll makes it easy for the plant to decompose the supplies of carbon dioxide which it takes in through its stomata.

FERNS

354. Structure, Form, and Habits of Ferns.— The structure of ferns is much more complex than that of any of the groups of cryptogamous plants discussed in the earlier portions of the present chapter. They are possessed of well-defined fibro-vascular bundles, they form a variety of parenchymatous cells, the leaves have a distinct epidermis and are provided with stomata.

Great differences in size, form, and habit of growth are found among the various genera of ferns. The tree ferns of South America and of many of the islands of the Pacific Ocean sometimes rise to a height of forty feet, while the most minute species of temperate and colder climates are not as large as the largest mosses. Some species climb freely, but most kinds are non-climbing plants of moderate size, with well-developed rootstocks, which are often, as in the case of the bracken-fern, or brake,[1] and in *Osmunda*, very large in proportion to the parts of the plant visible above ground.

355. Economic Value of Ferns. — Ferns of living species have little economic value, but are of great interest, even to non-botanical people, from the beauty of their foliage.

During that vast portion of early time known to geologists as the Carboniferous Age, the earth's surface in many parts must have been clothed with a growth of ferns more dense than is now anywhere found. These ferns, with other flowerless herbs and tree-like plants, produced the vegetable matter out of which all the principal coal beds of the earth have been formed.

[1] *Pteris aquilina.*

356. Reproduction in Ferns.—The reproduction of ferns is a more interesting illustration of alternation of generations than is afforded by mosses. The sexual plant, *gametophyte*, is the minute prothallium, and the non-sexual plant, *sporophyte*, which we commonly call the fern, is merely an outgrowth from the fertilized egg-cell, and morphologically no more important than the sporophyte of a moss, except that it supplies its own food instead of living parasitically. Like this sporophyte, the fern is an organism for the production of vegetative spores, from which new plants endowed with reproductive apparatus may grow.

THE STUDY OF A CLUB-MOSS (*LYCOPODIUM*)

357. Occurrence. — Several species of *Lycopodium* are common in rich woods in the northern and mountainous portions of the eastern United States. Any species may be studied.

358. Examination. — Note whether the plant is chiefly erect or prostrate and vine-like. Describe the mode of branching. Are the leaves arranged flat-wise or equally on all sides of the stem? Describe the leaves briefly. Are they all of one kind or do some portions of the plant evidently have smaller leaves?

Select fruiting specimens and determine the position of the sporangia. Is the leaf, near whose base each sporangium is situated, like the ordinary foliage leaves of the plant? Are the fruiting portions of the plant similar in general aspect or different from the rest of the plant and raised above it on stalks? Examine the spores. Are they all of one kind?

If *Selaginella* is used in place of *Lycopodium* or for comparison, two kinds of sporangia are to be sought, differing chiefly in shape. Describe each briefly. Compare the number of spores in each. The larger spores (*macrospores*) germinate and at length produce prothallia bearing archegonia, while the smaller produce prothallia bearing antheridia. The archegonia, after fertilization, develop each

an embryo. This grows, remaining for a time attached to the macrospore, and at length forms a new spore-plant.

THE STUDY OF A SCOURING-RUSH (*EQUISETUM*)

359. Occurrence. — The common horse-tail, *Equisetum arvense*, is widely distributed in the United States, east, west, north, and south. It is very often found on sand hills and along railroad embankments.

FIG. 212. — Plant of Lycopodium (*L. annotinum*).

The fruiting stems appear very early in the spring and are of short duration. The sterile vegetative growth follows, becoming well grown in June.

360. Examination of Rootstocks and Roots. — Examine the underground portions of the plant with reference to general size, position, color, shape, and position of notches. After studying the stems

above ground insert here any evident points of comparison. Do you find any special forms of stem development suited to a special purpose? Are there any organs in the nature of leaves?

FIG. 213. — A Scouring-Rush (*Equisetum sylvaticum*). At the right is a colorless fertile stem, in the middle a green sterile one, and at the left a green fertile one.

361. Sterile Stems. — Examine the stems above ground with reference to their color and mode and degree of branching. What is the character of the leaves? Do the stems in any sense serve as leaves? Observe the nodes composing the stem and note the position of the leaves on the stems. Do they appear to be placed several at the same level (whorled)?

Examine with a magnifying glass the surface of the stem and note the number of ridges and grooves. Compare the number and position of the leaves with reference to these.

362. Mineral Matter in Stem. — Treat small pieces of the stem with strong nitric acid to remove all vegetable substance and note the mineral substance remaining. Treat in a similar way thin cross-sections and examine under the microscope. The substance is silica. It gives the plant its gritty feeling and its name and use as "scouring-rush." Of what use is it to the plant? Use of the same substance in outer rind of corn stem, bamboo stem, and straw of grains?

363. Microscopic Examination. — Make thin cross-sections of the stem and examine under the lowest power of the microscope. Make a diagrammatic sketch to indicate the central cavity, the number and position of the fibro-vascular bundles, the cavity or canal in each, the ring of tissue surrounding the ring of bundles, and the larger cavities or canals outside of this. Where is the chlorophyll located? Can stomata be found, and if so, what is their location and arrangement?

364. Fertile Stems. — Describe the fruiting stem with reference to general aspect, size, color, number, and length of internodes, position of spore-bearing portion, color of spores in mass. Note the shield-shaped bodies (transformed leaves or *sporophylls*) composing the cone-like "flower" and see whether any joints can be detected where they are attached. Examine the inner surface of the shields for sporangia and spores. Examine the sporangia under a low power of the microscope. Examine some spores under a higher power. Note the two bands, *elaters*, on each spore, crossing each other and attached only at the point of crossing, forming four loose appendages. Watch these while some one moistens them by gently breathing upon them as they lie uncovered on the slide under the microscope

and note the effect. Also note the effect of drying. How does this affect the spores? Use of the bands?

365. Germination of Spores. — The spores germinate while fresh and form prothallia corresponding to those of ferns, but generally dicœcious. The prothallium which bears the antheridia remains comparatively small, and the antheridia are somewhat sunken. The others grow much larger and branch profusely. The terminal portion becomes erect and ruffled. Near this part the archegonia are formed, quite similar to those of ferns. The embryo plant developing from the germ-cell has its first leaves in a whorl. This at length grows into a spore-plant like that shown in Fig. 213.

About twenty-five species of *Equisetum* are known. Several may be looked for in any locality and may well be compared with the one described above, in regard to form, mode of branching, and mode of fruiting.

FIG. 214. — Part of a Lobe of the Mature Female Prothallium of *Equisetum*. (× about 50.)
a, mouth of a fertilized archegonium.

366. Fern-Plants (Pteridophytes). — The *Pteridophytes* (literally fern-plants) include in their general category not only ferns as commonly recognized, but several other small groups which are very interesting on account of their diversity. All cryptogams higher than mosses belong in this group. In moss plants the individuals growing from spores and bearing antheridia and archegonia, the gametophytes, are full-grown leafy plants, and the spore-bearing plant, or sporophyte, is merely a stalk bearing a spore-case. In all the fern-plants the reverse is true. The individuals growing from spores and bearing antheridia and archegonia are of

minor vegetative development (*prothallia*), while the spore-bearing plant is a leafy plant, even a tree in some ferns.

The ferns in the strictest sense have sporangia derived from the epidermis (transformed hairs), while a few plants closely resembling them in general aspect (*Botrychium*, etc.) have sporangia formed in the tissue of the leaf.

In the next subdivision, the water-ferns (Fig. 215), there is little resemblance to the common ferns. The sporangia are in special receptacles at the basal portion of the plant. The minute sexual plants are of two kinds, one, on germination, producing antheridia, the other archegonia. This group includes two rooting forms, *Marsilea* (with leaves resembling a four-leaved clover) and *Pilularia*, bearing simple linear leaves, and two floating forms, *Salvinia* (Fig. 215) and *Azolla*.

The remaining groups of fern-plants are the horse-tails and the club-mosses. The horse-tails have only one kind of spore and are peculiar chiefly in their vegetative aspect (Fig. 213), while the spore-bearing leaves, or sporophylls, are arranged in the form of a cone, as already shown.

The club-mosses include some plants which, as their name implies, have a superficial resemblance to a large moss, with the addition of a club-shaped stalked fruiting spike. These are the so-called "ground pines" and the running ground "evergreens" used for Christmas festoons in New England. Technically the group is distinguished by the possession of firm-walled sporangia formed singly near the bases of the leaves. The ordinary club-mosses already referred to have but one kind of spore, while plants called *Selaginella* and *Isoetes* have two kinds of spores, in this respect resembling *Marsilea*. In many

species of *Selaginella* the leaves are arranged flat-wise on the stem, so that considered physiologically the branching stem and its leaves together serve as a foliage leaf. In one of the commonest American forms, however, the stem is more nearly erect, and the leaves are all alike and four-ranked.

Isoetes (quill-wort) grows attached to the soil in shallow water at the bottoms of ponds. It has the aspect of short grass growing in bunches. The large sporangia are at the broad bases of the leaves.

367. High Organization of Pteridophytes. — The student may have noticed that in the scouring-rush and the club-moss studied there are groups of leaves greatly modified for the purpose of bearing the sporangia. These groups are more nearly equivalent to flowers than anything found in the lower spore-plants, and the fern-plants which show such structures deserve to be ranked just below seed-plants in any natural system of classification.

The variety of tissues which occur in pteridophytes is frequently nearly as great as is found in ordinary seed-plants, and the fibro-vascular system is even better developed in many ferns than in some seed-plants.

Starch-making is carried on by aid of abundant chlorophyll bodies contained in parenchyma-cells to which carbonic acid gas is admitted by stomata. In many cases large amounts of reserve food are stored in extensive root-stocks, so that the spring growth of leaves and stems is extremely rapid.

CHAPTER XXIII

THE EVOLUTIONARY HISTORY OF PLANTS

368. The Earliest Plant Life. — What sort of plants first appeared on the earth has never been positively ascertained. The oldest known rocks contain carbon (in the form of black lead or graphite) which may represent the remnants of plants charred at so high a temperature and under so great pressure as to destroy all traces of plant structure. Some objects supposed by many to be the remains of large algæ have been found in rocks that date back to a very early period in the life history of the earth, before there were any backboned animals, unless possibly some fishes. Judging from the way in which the various groups of plants have made their appearance from the time when we can begin clearly to trace their introduction upon the earth, it is probable that some of the simplest and lowest forms of thallophytes were the first to appear. Decaying animal or vegetable matter must have been less abundant than is now the case, so that a plant that could make part or all of its food from raw materials would have had a better chance than a saprophyte that could not. Water-plants are usually simpler than land-plants, so it is highly probable that some kind of one-celled aquatic alga was the first plant.

369. Fossil Plants. — *Fossils* are the remains or traces of animals or plants preserved in the earth by natural processes. Fossil plants, or parts of plants, are very

common ; the impressions of fern-leaves in bituminous coal and pieces of wood turned into a flint-like substance are two of the best known examples.

The only way in which we can get knowledge about the animals and plants that inhabited the earth's surface before men did is by studying such rocks as contain the remains of living things. In this way a great deal of information has been gained about early forms of animal life and a less amount about early plant life, — less because as a general thing plants have no parts that would be as likely to be preserved in the rocks as are the bones and teeth of the higher animals and the shells of many lower ones.

370. The Law of Recapitulation. — A highly important principle established by the study of the development of animals and plants from the egg or the seed, respectively, to maturity is this : *The development of every individual is a brief repetition of the development of its tribe.* The principle just stated is known as the law of recapitulation. As eggs develop during the process of incubation, the young animals within for a considerable time remain much alike, and it is only at a comparatively late stage that the wing of the bird shows any decided difference from the fore-leg of the alligator or the turtle. Zoölogists in general are agreed that this likeness in the early stages of the life history of such different animals proves beyond reasonable doubt that they all have a common origin, that is, are descended from the same kind of ancestral animal.

Among plants the liverworts and ferns supply an excellent illustration of the same principle. In both of the groups the fertilized egg-cells, as the student may have learned

by his own observations, are much alike. As the egg-cell grows and develops, the sporophyte of a liverwort, which proceeds from the egg-cell, is extraordinarily unlike the "fern" or asexual generation (sporophyte) among Filices. Now this progressive unlikeness between liverworts and ferns, as they develop from the fertilized egg-cell, points to the conclusion that both groups of plants have a common origin or that the more highly organized ferns are direct descendants of the less highly organized liverworts.

371. Plants form an Ascending Series. — All modern systems of classification group plants in such a way as to show a succession of steps, often irregular and broken, seldom leading straight upward, from very simple forms to highly complex ones. The humblest thallophytes are merely single cells, usually of microscopic size. Class after class shows an increase in complexity of structure and of function until the most perfectly organized plants are met with among the dicotyledonous angiosperms. During the latter half of the nineteenth century it first became evident to botanists that among plants *deep-seated resemblances imply actual relationship, the plants which resemble each other most are most closely akin by descent, and (if it were not for the fact that countless forms of plant life have wholly disappeared) the whole vegetable kingdom might have the relationships of its members worked out by a sufficiently careful study of the life histories of individual plants and the likeness and differences of the several groups which make up the system of classification.*[1]

[1] See Campbell's *Evolution of Plants* and Warming's *Systematic Botany*, Preface and throughout the work. In the little flora of the present book, the families are arranged in the order which, according to the best recent German authorities, most nearly represents their relationships.

372. Development of the Plant from the Spore in Green Algæ, Liverworts, and Mosses. — The course which the forms of plant life have followed in their successive appearance on the earth may be traced by the application of the law above named. Such algæ as the pond-scums produce spores which give rise directly to plants like the parent.

In many liverworts the spore by its germination produces a thallus which at length bears antheridia and archegonia. The fertilized egg finally develops into a sporophyte which remains attached to the thallus, although it is really a new organism. Liverworts, then, show an alternation of generations, one a sexual thallus, the gametophyte, the next a much smaller, non-sexual sporophyte, and so on.

A moss-spore in germination produces a thread-like protonema which appears very similar to green algæ of the pond-scum sort. This at length develops into a plant with stem and leaves, the sexual generation of the moss. The fertilized egg finally matures into a sporophyte which is the alternate, non-sexual generation. This is attached to the moss-plant, or gametophyte, but is an important new organism. In the moss, as in the liverwort, the sexual generation is the larger and the more complex ; the non-sexual generation being smaller and wholly dependent for its food supply on the other generation, to which it is attached.

373. Development of the Plant from the Spore in Pteridophytes. — In the pteridophytes there is an alternation of generations, but here the proportions are reversed, the prothallium, or sexual generation, or gametophyte, being short-lived and small (sometimes microscopic), and the

non-sexual generation, the sporophyte, often being of large size. The ferns (non-sexual generation), for instance, are perennial plants, some of them tree-like.

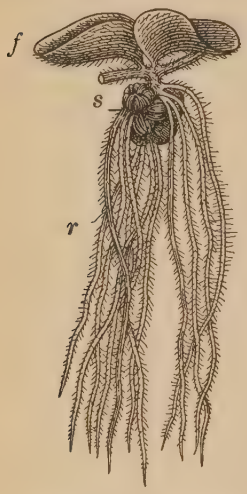


FIG. 215.—A Water-Fern (*Salvinia*).

Some pteridophytes, as the *Salvinia*, a small floating aquatic plant, sometimes known as a water-fern (Fig. 215), produce two kinds of spores, the large ones known as *macrospores*, and the small ones known as *microspores* (Fig. 216). Both kinds produce microscopic prothallia, those of the former bearing only archegonia, those of the latter only antheridia. From the prothallia of the macrospores a plant (non-sexual generation) of considerable complexity of structure is formed.

374. Parts of the Flower which correspond to Spores. — In seed-plants the spore-formation of cryptogams is represented, though in a way not at all evident without careful explanation. The carpel is the macrospore-producing leaf or *macrosporophyll*, and the stamen is the microspore-producing leaf or *microsporophyll*. Pines and other gymnosperms produce a large cell (the embryo sac) in the ovule (Fig. 217), which corresponds to the macrospore, and a pollen grain which represents the microspore. In its

FIG. 216.—Two Indusia of *Salvinia*. *mi*, microspores; *ma*, macrospores.

development the macrospore produces an endosperm which is really a small cellular prothallium, concealed in the ovule. The microspore contains vestiges of a minute prothallium.

In the angiosperms the macrospore and its prothallium are still less developed, and the microspore, or pollen grain, has lost all traces of a prothallium and is merely an antheridium which contains a generative cell. This cell, while inside the pollen-grain or after entering the tube, divides into two *sperm nuclei* which form *sperm cells*.[1]

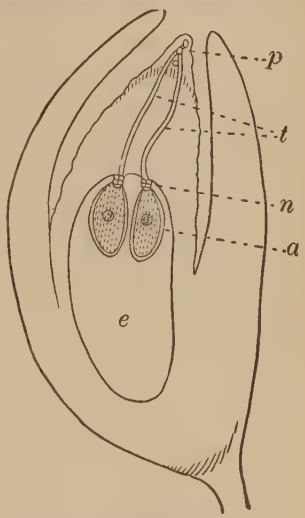


FIG. 217. — Longitudinal Section through Fertilized Ovule of a Spruce.

p, pollen grains; *t*, pollen tubes; *n*, neck of the archegonium; *a*, body of archegonium with nucleus; *e*, embryo sac filled with endosperm.

Phanerogams are distinguished from all other plants by their power of producing seeds, or enclosed macrosporangia, with embryos.

375. The Law of Recapitulation and the Relationships of the Great Groups of Plants. — On summing up Sects. 372–374 it is evident that the sexual generation in general occupies a less and less important share in the life of the plant as one goes higher in the scale of plant life.[2] In the case of the rockweed, for instance, the sexual generation is the plant. Among mosses and liverworts the sexual

[1] For a much fuller account of the subject see Bergen and Davis' *Principles of Botany*, pp. 376–387, Ginn & Company.

[2] A good many plants of low organization, however, are not known to pass through any sexual stage.

generation is still very prominent in the life of the plant. Ordinary ferns show us the sexual generation existing only as a tiny independent organism, living on food materials which it derives from the earth and air. In the *Salvinia* it is reduced to microscopic size and is wholly dependent on the parent-plant for support. Among seed-plants the sexual generation is so short-lived, so microscopic, and so largely enclosed by the tissues of the flower that it is comparatively hard to demonstrate that it exists.

The fact that the life history of so many of the classes of plants embraces a sexual stage, in which an egg-cell is fertilized by some sort of specialized cell produced wholly for use in fertilization, tends strongly to show the common origin of the plants of all such classes. We have reason to believe, from the evidence afforded by fossils, that plants which have only a sexual generation are among the oldest on the earth. It is therefore likely that those which spend the least portion of their entire life in the sexual condition were among the latest of plants to appear. Then, too, those which have the least developed sexual generation are among the latest of plants. Judged by these tests the angiosperms must be the most recently developed of all plants.

If one were to attempt to arrange all the classes of existing plants in a sort of branching series to show the way in which the higher plants have actually descended from the lower, he would probably put some one of the green algæ at the bottom and the angiosperms at the top of the series.

376. The Oldest Angiosperms. — It is impossible to give any of the reasons for the statements of this section

without making an unduly long chapter. Briefly, it may be stated that the monocotyledons are the simplest but perhaps the youngest angiosperms; the dicotyledons are higher in organization but came earlier. The descent and various relationships of the families of dicotyledons can be discovered by the study of the flower, fruit, and seed better than by the examination of the vegetative organs.

The entire pedigree of the several families cannot be represented by arranging the names of the families in a straight line. It is, however, in a general way, as indicated by the succession of families in the Flora which accompanies this book, the Willow Family being perhaps the oldest (of the more familiar ones) and the Composite Family the youngest.

Part II

ECOLOGY

CHAPTER XXIV

PLANT SOCIETIES

377. Ecology. — Plant ecology includes all that portion of botany which has to do with the way in which plants get on with their animal and plant neighbors, and especially the way in which they adjust themselves to the nature of the soil and climate in which they live. Ecology, in short, discusses the relations of plants to their surroundings or environment. A good deal of what has been said in previous chapters about such topics as parasitic plants, the occurrence of winter bud-scales, the movements of leaves, the coating of hairs on stems and leaves, the storage of water in epidermis-cells, is really ecological botany, although it is not so designated in the sections where it occurs.

378. Plant Societies. — In a single acre of woodland, of marsh, or of meadow, there will usually be found a large number of species of plants. One species may be sufficiently abundant and conspicuous to give a name to the whole tract, so that it may, for instance, be recognized as a bit of birch wood or of cat-tail swamp. But under the birches and among the cat-tails there are plants, it may

be, of a hundred other kinds, the seed-plants not all in bloom at any one season, but coming along in succession from earliest spring until the approach of winter. The entire set of plants which naturally occupies a given area of land under somewhat uniform conditions is called a *plant society* or *plant formation.*

379. Similar Societies due to Similar Conditions. — As soon as the young botanist begins to collect plants in a set of localities new to him, he discovers that his old acquaintances are still to be found grouped as he has been accustomed to see them. The rich black loam of a wooded bank a hundred miles away from his familiar collecting ground will show the same assemblage of slippery elms and lindens, red buds, bladdernuts, and wahoos, hepaticas, bloodroots, Dutchman's breeches, trilliums, pepper root, and wild ginger, with a multitude of later-blooming herbaceous plants, that he has learned to know so well. The muddy borders of ponds from Maine to Minnesota and beyond are fringed with the same kinds of bur-reeds and sedges, set with water-plantain, and decorated with the soft white blossoms of the arrowhead. The sand dunes along the northern Atlantic coast and those that border Lake Michigan are clothed with a sparse vegetation which in both cases includes the little beach plum, such coarse grasses as that shown in Plate I, and the straggling sea rocket. Barnyards and waste grounds about farm buildings from Massachusetts to Missouri contain such weeds as the dog fennel, the low mallow ("cheeses"), motherwort, catnip, and some smartweeds.

A little study of such cases soon leads one to the conclusion that these plant societies and multitudes of others

exist *because all the plants in each society are adapted to their special environment.* Wherever such an environment occurs such a society will be found in it,[1] or, if not already there, will flourish when introduced.

380. Similar Species replace Each Other. — Two sets of localities alike in many respects but unlike in some points are often inhabited by different species of the same genus. For instance, the pine barrens of New England and the adjacent states are commonly covered with the northern pitch pine, while far southward, in sandy soil, its place is taken by the long-leaved pine. Along streams and swamps northward the speckled alder is generally found, while southward the smooth alder is most common. In rich woods of the northeastern United States the painted trillium and the erect trillium ("Benjamin," or "squaw root") are the commonest species, while far south, in similar localities, the sessile trillium, Underwood's trillium, and the large-flowered trillium are abundant.

In all such cases — and they are very numerous — we are to infer that the genus is peculiarly well adapted to some especial set of conditions, as sandy soil, brooksides, or the rich, shaded soil of woodlands. But the more northerly species are capable of enduring the severe winters and brief summers of their region, while the more southerly ones perhaps cannot do so. The relative warmth of the climates in which they live may not be the only reason, or even the principal reason, for the distribution of such plants as those just mentioned, but it is one factor at any rate. And it is certain that, on the whole, most of our

[1] That is, in localities not separated by such natural barriers as seas, high mountains, or deserts.

native and thoroughly naturalized plants are growing under what is, for them, the best environment, since they cannot usually be made to exchange places with each other. If a square mile of land in Louisiana were to be planted with Minnesota species, and a square mile in Minnesota with Louisiana species, it is very improbable that either tract, if left to itself, would long retain its artificial flora. To this rule there are, however, important exceptions (see Sect. 457).

381. Plant Formations of Few Species. — It is not uncommon to find tracts of land or water inhabited by great numbers of plants of the same species so as almost to exclude all other plants except microscopic cryptogams. Ponds and sluggish streams are often filled in this way with the water hyacinth or the American lotus. The canebrakes of the south and the wild rice swamps along northern lakes and rivers are other examples of an extremely simple flora spread over large areas. Prairies not infrequently for hundreds of square miles are covered mainly (not entirely) with a few kinds of grasses as the great plains are with sagebrush.

382. Ecological Classification of Plants. — The ordinary classification of plants, as set forth in Chapter XIX, is based, as far as possible, on their actual relationships to each other. But when plants are classified ecologically they are grouped according to their relations to the world about them. They may, therefore, be gathered into as many (or more than as many) different groups as there are important factors influencing their modes of life. We may classify plants as light-loving and darkness-loving, as requiring free oxygen and not requiring it, and so on.

Indeed, one of the most useful classifications of bacteria, for practical purposes, is into species which must have free oxygen, that is, oxygen not chemically combined with other substances, in order to grow and increase, and those which can live without it.

The most important consideration in classifying seed-plants on ecological grounds is based on their requirements in regard to water. Grouped with reference to this factor in their life all plants may be classed as:

(1) *Hydrophytes*, or water-loving plants.
(2) *Xerophytes*, or drought-loving (or perhaps drought-tolerating) plants.
(3) *Mesophytes*, or plants which thrive best with a moderate supply of water.

These three classes do not fully express all the relations of plants to the water supply, so two others are found convenient.

(4) *Tropophytes*, or seasonal plants which are hydrophytes during part of the year and xerophytes during another part.[1]
(5) *Halophytes*, or salt marsh plants and "alkali" plants, species which can flourish in a very saline soil.

383. Difficulties in Ecological Classification. — It seems at first sight a simple matter to group plants in regard to their need of water. There can be no difficulty in classifying as hydrophytes all plants like the bladderworts, water cresses, certain mosses, and many lower spore-plants which live only in water. Cactuses, aloes, and similar plants are recognized at sight as xerophytes. But the chief difficulty

[1] The plants which E. Warming, one of the foremost authorities, classes as mesophytes are many of them grouped by another great authority, A. F. W. Schimper, as tropophytes.

is in dividing mesophytes from the other two classes, into which they shade by indefinite gradations. In order to know whether the plants of a region have plenty of water or not, we must know not only how many inches of yearly rainfall there are, but also what the soil is like, what is the temperature of the soil and air, whether or not there are dry winds, and whether there are fogs or heavy dews. A lichen on a bare rock may be living almost under

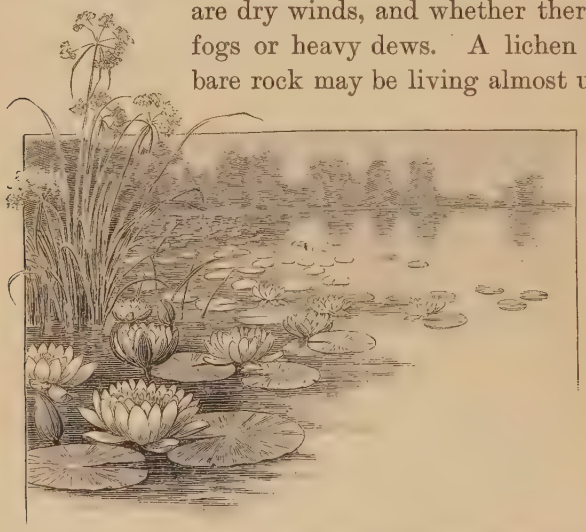


FIG. 218. — Aquatic Plants: Pond-Lilies with Floating Leaves and Sedges with Aërial Leaves.

desert conditions, while a pitcher-plant in a bog near by has its roots in standing water (or in ice) nearly all the year round.

384. Hydrophytes. — Some of these are herbaceous aquatic plants, like the duckweed, the pickerel-weed, the pond-lily, and the water-crowfoot; others, such as the "calla" (*Richardia*), the buckbean, the cat-tail, and the sweet flag, many ferns, mosses, and liverworts, prefer

damp air and soil. All of them transpire freely, and many of them cannot live at all under the moisture conditions which suit ordinary plants.

Some aquatics have their leaves wholly submerged, others, such as the duckweed and the pond-lilies (Fig. 218), have them floating, and still others, like the sedges in the same picture, have their leaves freely exposed to the air. A few plants have both water-leaves and air-leaves (Fig. 219). Some aquatic plants are rooted in the mud, while others have no roots at all, or, like the duckweed, have only water-roots.

FIG. 219. — Submerged and Aërial Leaves of a European Crowfoot (*Ranunculus Purshii*). The leaf with thread-like divisions is the submerged one.

The leaves of land-plants in very rainy, subtropical climates are exposed to the attacks of parasitic spore-plants which flourish on their surfaces. To ward off the attacks of these it is necessary to keep water from accumulating on the surfaces of the leaves. This result is secured by a waxy deposit on the epidermis and also by the slender prolongation to drain off surplus water, shown in Fig. 221. That this slender leaf tip is useful in the way suggested is proved by the fact that when it is cut squarely off the leaf no longer sheds water freely.

385. Xerophytes. — A *xerophyte* is a plant which is capable of sustaining life with a very scanty supply of water. Since the first plants which existed were aquatics

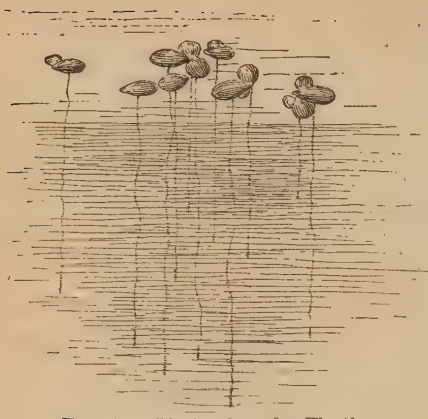


FIG. 220. — The Duckweed, a Floating Aquatic Plant.

(Sect. 368), we must consider that xerophytes are highly specialized and modified forms adapted to extremely trying conditions of life. A typical xerophyte is one which can live in a very dry soil in a nearly rainless region. The yucca in Plate VII and the melon-cactus (Fig. 49) are good examples of such plants. Less extremely xerophytic are plants like the date-palm (Fig. 54), which flourishes in the oases of the Sahara, where the soil is moist from the presence of springs, though rains are almost unknown, or the houseleeks and stonecrops found in many gardens, the so-called Spanish moss (Plate IV), and lichens (Figs. 198, 199), all of which grow most rapidly in moist air, but cling to bare rocks and trunks of trees, from which they get no water. A xerophyte must be capable of storing water and transpiring very slowly, like cactuses, aloes, stonecrops, and such fleshy plants

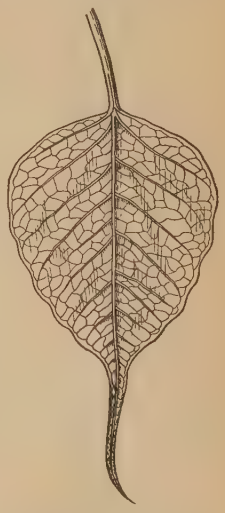


FIG. 221. — Leaf of an East Indian Fig Tree,[1] with a Slender Tapering Point to drain off Water.

[1] *Ficus religiosa.*

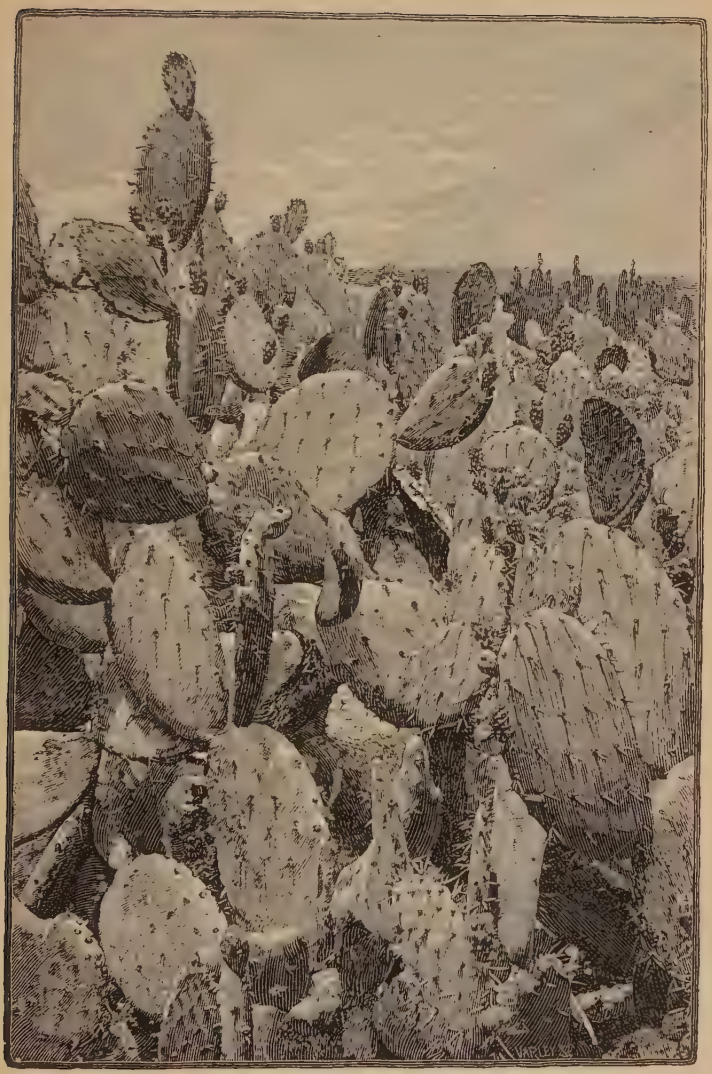


FIG. 222. — A Field of Prickly-Pear Cactus Plants : Xerophytes.

with a thick epidermis, or else it must be able to revive after being thoroughly dried. A few seed-plants and many such spore-plants as lichens, *Pleurococcus* (Sect. 277), yeast, and some bacteria (Sect. 263), thrive just as well after remaining for some months or years in a dried condition as they did before drying. A good illustration of this fact as regards yeast is found in the use of dried yeast cakes, made of a mixture of yeast and corn meal. These will raise dough promptly when mixed with it, even if they have been kept dry for a year or more.

FIG. 223. — *Harpagophytum*, a South African Xerophyte.

386. Roots and Stems of Xerophytic Seed-Plants. — Some xerophytes have roots which show no peculiarities of form or structure, but many make special provision for storing food and water in their roots. Such roots are fleshy and often, as in *Harpagophytum* (Fig. 223), are of great size compared with the portion of the plant above the ground.

Xerophytic stems are frequently very thick in proportion to their length, sometimes even globular, and they commonly contain large amounts of water. In leafless plants, like the cacti, the surface for transpiration is much less than that offered by leafy plants. Many species which bear leaves shed most of them at the beginning of the dry season, and some remain thus in a half dormant condition for long periods, as is the case with many *Euphorbias*

PLATE VII. — Tree Yucca in the Mohave Desert

(Fig. 245). The epidermis, even on the younger portions of the stem, is highly cutinized (Fig. 121), and this structure makes any evaporation very slow.

387. Leaves of Xerophytes. — In regions where the greatest dangers to vegetation arise from long droughts and the excessive heat of the sun, the leaves of plants usually offer much less surface to the sun and air than is the case in temperate climates. Sometimes the blade of the leaf is absent and the expanded petiole answers the purpose of a blade, or, again, foliage leaves are altogether lacking, as in the cactuses (Fig. 222), and the green outer layers of the stem do the work of the leaves.

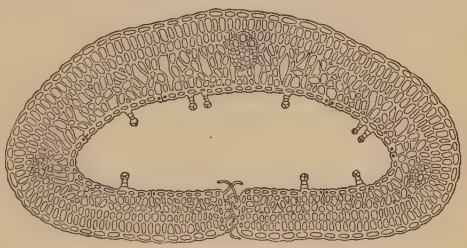


FIG. 224. — Cross-Section of Rolled-Up Leaf of Crow-Berry (*Empetrum nigrum*). (Magnified.)

388. Rolled-Up Leaves. — Leaves which receive but a scanty supply of water are often protected from losing it too rapidly by being rolled up, so that the evaporating, *i.e.*, stomata-containing, surface is on the inside of the roll. Sometimes, as in the crow-berry (Fig. 224), the curled condition is permanent. In other plants, as in such grasses as *Stipa* (Fig. 225), and in Indian corn, the leaf rolls up when the weather is very dry and unrolls again when it receives a better supply of water.

389. Mesophytes. — A mesophyte is a plant which thrives best with a moderate supply of water. The great majority of the wild and the cultivated plants of the United States are mesophytes, and what has been learned

from Part I of this book about the forms, structure, and habits of ordinary plants, together with what the student's own observation, aside from the study of botany, has taught him, should suffice to give him a fair idea of mesophytic plant life.

The typical mesophyte of the northern United States is an annual, since most of our larger perennials pass the winter in a xerophytic condition, to avoid destruction by drying up during the long period when the roots can absorb little or no water from the frozen soil. Our evergreen coniferous trees, such as pines, spruces, cedars, and so on, have leaves of decidedly xerophytic structure. So also do such evergreen shrubs as the rhododendrons, wintergreen, arbutus, holly, and bearberry. Our deciduous trees and shrubs and most perennial herbs are tropophytes (Sect. 390).

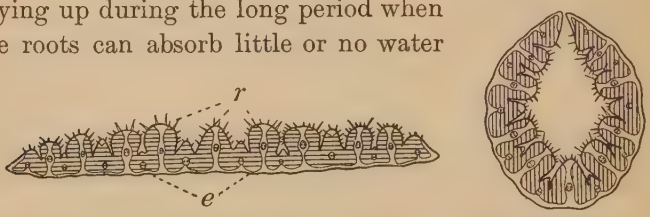


FIG. 225. — Cross-Section of Leaves of a Grass,[1] unrolled for Exposure to Sunlight and rolled up to prevent Evaporation.

r, ridges of the upper epidermis, with many stomata on their surfaces; *e*, thick lower epidermis, without stomata.

390. Tropophytes, or Seasonal Plants. — Examples of these are most deciduous trees and the majority of the perennials of temperate regions, for instance oaks, elms, birches among trees, and tulips, crown imperials, lilies, hyacinths, spring-beauties, peonies, dahlias, and potatoes among herbs. Such plants have a pretty large surface for

[1] *Stipa capillata.*

transpiration during the summer (or in regions like Southern California in the rainy season) and a greatly reduced surface during the winter (or the dry season).

In the case of trees the reduction of surface is brought about by the fall of the leaves (Sect. 186), and in the case of herbaceous perennials it is secured by the death of the green stem and the leaves, so that only a compact root, rootstock, or bulb is left alive underground. That is to say, the perishable or annual part of tropophytes has the characteristics of mesophytes or even of moisture-loving plants, while the perennial part is constructed on the plan of xerophytes.

391. Halophytes. — A halophyte is a plant which can thrive in a soil containing much common salt or other saline substances. The seaside obviously occurs to one as the region of halophytic vegetation, but many inland areas contain halophytic plants, for instance the neighborhoods about salt springs and the "alkali" lands of the southwest and the Pacific Slope. The presence of salt in the soil renders absorption of the soil-water comparatively difficult, since osmosis takes place more readily between ordinary water and the liquid

FIG. 226. — The Mangrove, a Halophytic Tree of Southern Florida and the Tropics.

contents of root-hairs and young roots than between salt water and the liquids inside the root. Halophytes, therefore, are put on short rations as regards water, even though they may be growing in a watery marsh. Consequently halophytes often have much the appearance of fleshy xerophytes and the structure of xerophytes.

The mangrove tree (Fig. 226) is one of the most remarkable of halophytes. It grows in shallow water along the seashore and sends out many aërial roots which at length find their way down into the salt mud. In this way it collects drift material and gradually extends the shore line farther out to sea.

392. Other Kinds of Ecological Classes. — It is easy to class plants according to their habits in many other regards than according to their relative power of transpiration (see Chapter XXVI). Only one other kind of classification need, however, be mentioned in this chapter, that is, the division into sun-loving and shade-loving plants. Even in very dense forests some plants will be found growing on the soil in the twilight formed by the shade of the trees. Some of this undergrowth is of seed-plants, and there are many ferns and mosses which flourish in such situations. Shade-plants commonly have large pale leaves, and generally (except in ferns) the leaves are not much cut or lobed (Fig. 227, I). Sun-loving plants, on the other hand, usually have comparatively little leaf-surface, and the leaves are often cut into narrow divisions (Fig. 227, II). Apparently the broad leaf-surfaces in the one class are to expose many green cells to the light for starch-making, while in the other class the slender leaf-divisions expose enough assimilating cells, and at the same time the

narrowness of the division permits plenty of light to penetrate to the plant's lower leaves. It is also, doubtless, much easier for leaves like those of the yarrow, the dog fennel, the tansy, the carrot, and their like, to withstand the action of severe winds, to which they are often exposed, than it would be for leaves like those of the jack-in-the-pulpit (see Frontispiece), the trilliums, the lily-of-the-valley, and similar leaves.

FIG. 227. — I, a Shade-Plant (*Clintonia*); II, a Sun-Plant, Dog Fennel (*Anthemis*).

393. Transition of a Plant from Shade Conditions to Sun Conditions. — It is characteristic of many kinds of forest trees that the young seedlings are much more tolerant of dense shade than the adult trees are. Sometimes their seeds will hardly germinate at all unless thoroughly shaded, and the young trees for the first few years flourish best in the shade. Afterwards most trees need a good deal of sunlight, but they may live long with a scanty supply of light. The red spruce sometimes

FIG. 228. — An Epiphytic Fern (*Platycerium*) on a Tree Trunk.

The more upright leaves next the trunk of the tree serve to collect water and to accumulate a deposit of decaying vegetable matter, while the outer leaves serve as foliage and bear spores.

lingers on for fifty or a hundred years, reaching meantime a diameter of not more than two inches, and then, on getting more light, shoots up into a large and valuable timber tree.[1]

394. Epiphytes. — It is even easier for a plant to secure enough sunlight in a forest region by perching itself upon the trunk or branches of a tree than by climbing, as our wild grapevines and the great tropical lianas do. There is a large number of such perched plants, or *epiphytes*, embracing species of many different groups of seed-plants and of spore-plants. The fern shown in Fig. 228 is a good example of an epiphyte. Instances among seed-plants are the so-called Florida moss (Plate IV) and orchids like those in Fig. 13.

[1] See the *Primer of Forestry*, Part I, U. S. Department of Agriculture, 1899, pp. 33–35.

CHAPTER XXV

BOTANICAL GEOGRAPHY

395. Regions of Vegetation. — The earth's surface (that of the land) has been described by one of the greatest of geographical botanists[1] as divided into twenty-four regions of vegetation. This classification takes account of all the principal continental areas which have a characteristic set of plants of their own, as well as of the most important islands. But a simpler arrangement is to consider the plant life of the earth as distributed among the following regions:

1. The tropical zone.
2. The temperate zones.
3. The arctic zones.
4. Mountain-heights.
5. Bodies of water.

Any good geography gives some account of at least the land vegetation of the earth. It is necessary in the present chapter only to point out a few of the most important characteristics of the plants of the zones and other areas mentioned above and to give some reasons why the plant population of each has its special characteristics.

396. Tropical Vegetation. — Within the tropics two of the great factors of plant life and growth, namely, light and heat, are found in a higher degree than elsewhere on the earth. Moisture, the third requisite, is in some

[1] A. Grisebach.

regions very abundant (over sixteen feet of rainfall in a year) or sometimes, in desert areas, almost lacking. We find here, accordingly, the greatest extremes in amount of vegetation, from the bare sands or rocks of the Sahara desert (Fig. 229) to the densely wooded basin of the Kongo and of the Amazon. Xerophytic plants, many of them with extremely complete adaptations for supporting life for long periods without water, are characteristic of tropical deserts, while many of the most decided hydrophytes among land-plants are found in the dripping sub-

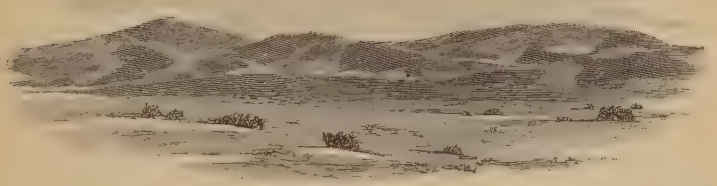


FIG. 229. — Hills of Drifted Sand in the Sahara.

tropical forest interiors. Throughout a large part of the zone, reaching five degrees each way from the equator, there are daily rains the year round.

397. Vegetation of the Temperate Zones. — We are all familiar in a general way with the nature of the plant life of the north temperate zone; that of the south temperate is in most ways similar to our own. Most of the annuals and biennials are of a medium type, not decided xerophytes nor hydrophytes, and the perennials are mainly tropophytes. There are no desert areas so large or so nearly destitute of plants as those found in subtropical regions, neither are there any such luxuriant

growths as occur in the rainy forest regions of the tropics. On the other hand, the largest trees on earth, the "big trees," or Sequoias (Fig. 32), occur in the temperate portion of North America, along the Sierra Nevada, and the taller, though less bulky, gum trees (*Eucalyptus*) of Australia grow in a warm temperate region.

398. Temperate Plant Societies due to Special Conditions of Soil. — Even where the climate is a moderate one as regards temperature and rainfall, peculiar soils may cause the assemblage of exceptional plant societies. Some of the most notable of such societies in temperate North America are those of the salt marshes, the sand dunes, and the peat bogs.

FIG. 230. — A Halophytic Plant (*Salicornia*).

In salt marshes the water supply is abundant, but plants do not readily absorb salt water by their roots, so that the plants which grow in salt marshes usually have something of the structure and appearance of xerophytes. Some of them are fleshy (Fig. 230), and some species are practically leafless.

Sand dunes, whether along the seacoast or near the great lakes, offer a scanty water supply to the roots during much of the year, and the soil-water contains less of the raw materials for plant food than is offered by that of ordinary soils. Many grasses thrive, however, in these shifting sands (Plate I), and some, like the beach-grass

(*Ammophila*) of the Atlantic coast and the great lakes, will continue to grow upward as the sand is piled about them by the winds until they have risen to a level of a hundred feet above the starting point.

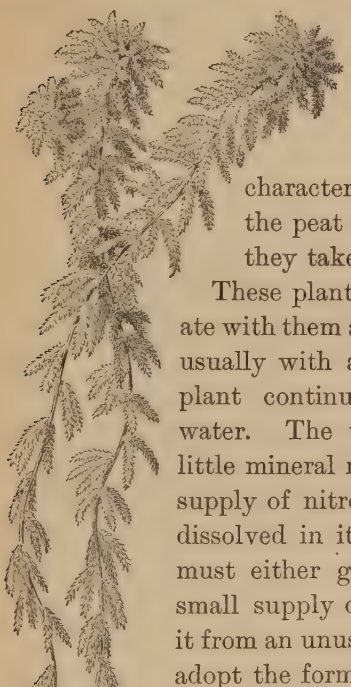


Fig. 231. Peat Moss.

Peat bogs are especially characterized by the predominance of the peat mosses (Fig. 231) from which they take their name.

These plants and the others which associate with them are mostly hydrophytes, living usually with a considerable portion of the plant continually submerged in the bog water. The water of such bogs contains little mineral matter and only a very scanty supply of nitrogen, in the form of nitrates dissolved in it. The bog-plants, therefore, must either get on with an exceptionally small supply of nitrogen or they must get it from an unusual source. The peat mosses adopt the former alternative, while the sun dews (Fig. 238), the pitcher-plants (Fig. 237), and some other species adopt the latter and derive their nitrogen supply largely from insects which they catch, kill, and digest.

399. Arctic Vegetation. — The seed-plants of the arctic flora are mostly perennials, never trees. By the large bulk of the underground portion as compared with that of the part above ground, they are adapted to a climate in which they must lie dormant

for not less than nine months of the year. The flowers are often showy and appear very quickly after the brief summer begins. Mosses and lichens are abundant, — the latter of economical importance because they furnish a considerable part of the food of reindeer.

400. Mountain or Alpine Vegetation. — In a general way the effect of ascending a mountain, so far as vegetation is

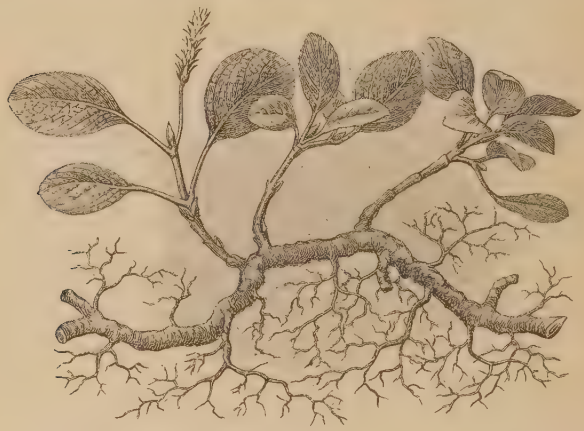


FIG. 232. — A Plant of Arctic Willow. (About natural size.)

concerned, is like that of traveling into colder regions. It was long ago suggested, in regard to Mount Ararat, that on ascending it one traversed first an Armenian, then a South European, then a French, then a Scandinavian, and finally an arctic flora. Up to a certain height, which varies in different latitudes, the slopes of mountains are very commonly forest-covered. The altitude up to which trees can grow (or as it is commonly called in this country the "timber line") is somewhat over twelve thousand feet

in the equatorial Andes and lessens in higher latitudes as one goes either way from the equator. In the White Mountains, for instance, the timber line only rises to about four thousand five hundred feet. The seed-plants of alpine regions in all parts of the earth have a peculiar and characteristic appearance. It is easiest to show how such plants differ from those of the same species as they look when

FIG. 233. — Trees near the Timber Line on the Slope of Pikes Peak.

growing in ordinary situations by reference to the plants themselves or to good pictures of them (see Fig. 235). The differences between alpine and non-alpine plants of the same or closely related species have been summed up as follows:[1]

"The alpine individuals have shorter stems, smaller leaves, more strongly developed roots, equally large or somewhat larger and usually somewhat more deeply colored flowers, and their whole structure is drought-loving (xerophilous)."

[1] By A. F. W. Schimper.

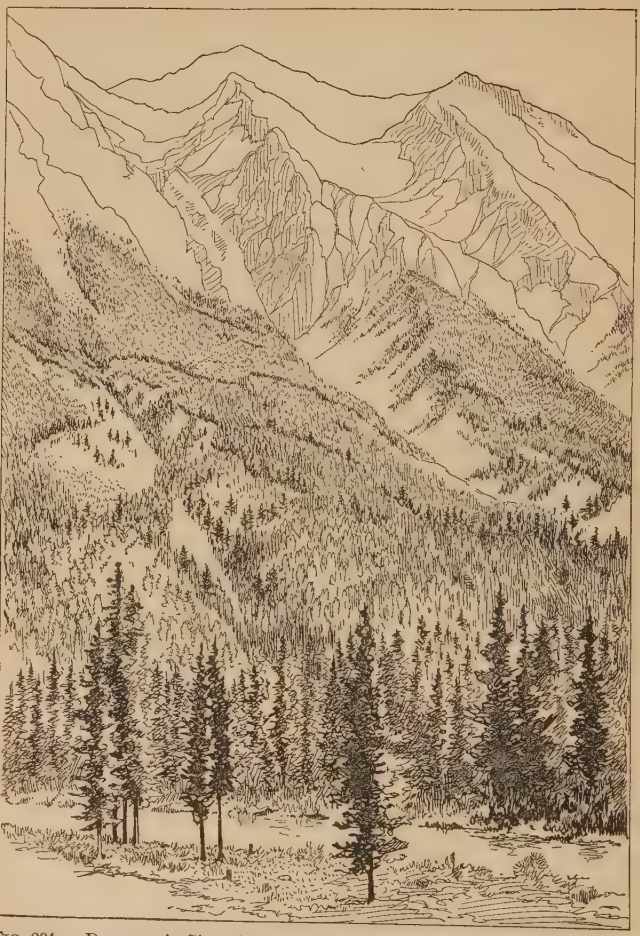


FIG. 234. — Decrease in Size of Trees at High Elevations (Canadian Rockies).

Trees at great elevations become much gnarled and stunted, as their growth is necessarily very slow (Fig. 233). The gradual diminution of the height of the

trees on ascending a mountain is well shown in Fig. 234. The treeless character of the mountain summit is also plain.[1]

Recent experiments have shown that many ordinary plants promptly take on alpine characteristics when they are transferred to moderate heights on mountains. For instance, a rather commonly cultivated sunflower,[2] when planted at a height of about six thousand five hundred feet, instead of having a tall leafy stem produces a rosette of very hairy leaves lying close to the ground, thus becoming almost unrecognizable as a sunflower. The change was even greater than that shown in the rock rose (Fig. 235) cultivated by the same experimenter. The peculiarities of alpine plants appear to be due mainly to the intense light which they receive during the daytime,

FIG. 235. — Two Plants of Rock Rose (*Helianthemum*). (Both drawn to the same scale.)
A, low ground form ; *B*, alpine form.

[1] Part of the diminution is only apparent, — the effect of distance, — but the growth at the highest levels is often less than waist high.

[2] *Helianthus tuberosus*, the so-called Jerusalem artichoke.

to the strongly drying character of the air in which they grow (due partly to its rarefaction), and to the low temperature which they must endure every night.

401. Aquatic Vegetation. — Plants which live wholly in water often need a less complicated system of organs than land-plants. True roots may be dispensed with altogether, as in many seaweeds, in most fresh-water algæ, and in some seed-plants. A few such plants have mere holdfasts that keep them from drifting with the waves or the current. Sometimes roots may, as in the duckweeds (Fig. 220), serve the purpose of a keel and keep the flat, expanded part of the plant from turning bottom up. The tissues that give strength to the stems and leaves of land-plants are not usually much developed in submerged aquatics, since the water supports the weight of such plants. In some algæ, as the common rockweed or bladder-wrack (Fig. 183), the weight of the plant is admirably buoyed up by large air-bladders. Transpiration is done away with, and whatever carbonic acid gas or oxygen is absorbed or given off passes directly through the cell-walls into the interiors of the cells. Generally water-plants do not reach any great size, but some species are the longest of known plants, *Macrocystis*, the great kelp of the Pacific Ocean, attaining, it is said, the length of a thousand feet or more. In spite of the moderate size of most algæ the total bulk in the various oceans must be extremely large. The Sargasso Sea alone, in the Atlantic Ocean, reaches most of the way from the Bahamas to the Azores and extends over seventeen degrees of latitude. The whole area is occupied by a nearly compact mass of floating seaweed.

Besides the comparatively well-known and readily seen larger algæ there is a great amount of vegetation floating in what is known as the *plankton*. This is a mass of microscopic animals and plants, found floating scum-like or submerged in fresh and in salt water and often accumulated in great quantities near shores, to which it is swept by the action of the wind and waves and currents. Much of the plant life of the plankton, both of fresh and of salt water, often consists of the flinty-shelled one-celled microscopic algæ known as diatoms (Fig. 176).

402. Botanical Geography of the United States. — All of the continuous territory of the United States[1] lies in the north temperate zone. There is material for a large volume in the discussion of the distribution of plants over our territory in this continent alone, but it is possible to sum up a mere outline of the matter in a very few words. Excluding the floras of many single mountains and mountain ranges, the land surface of the country may for botanical purposes be divided into four great areas, as follows:

1. *The Forest Region.* — This occupies the eastern and central portion of the United States. It is bounded on the west by an irregular line, most of which lies to the eastward of the hundredth meridian. In some places this forest boundary extends eastward across the Mississippi River, while in others it recedes from the river five hundred miles or more to the westward.

2. *The Great Plains Region.* — This extends westward from the region above named to the Rocky Mountain Plateau.

[1] That is, not counting in Alaska, our West Indian possessions, the Sandwich Islands, or the Philippines.

3. *The Pacific Highland Region.* — This includes the Rocky Mountains, the Sierra Nevada, and the various plateaus between them.

4. *The Pacific Slope.* — This extends from the Cascade Range and the Sierra Nevada to the sea.

403. Characteristics of the Four Regions. — The forest region is mainly remarkable for its great variety of hardwood trees, of which it contains a larger number of useful species than any equal area of the earth with a temperate climate. In the northeasterly portion and in much of the southerly portion there are extensive forests of the cone-bearing evergreens, such as pines, spruces, hemlocks, and cedars. The vegetation is in general such as thrives in medium conditions as regards heat and rainfall.

The plains region is largely covered with grasses, many of them xerophytes. Some of the most characteristic plants associated with the grasses are Compositæ, such as sunflowers, rosin-weeds (*Silphium*), cone-flowers, gum-weeds (*Grindelia*), and blazing-stars (*Liatris*).

The Pacific highland region includes a very great variety of plant societies, from the heavily wooded mountain slopes and valleys to high sterile plains which are almost deserts. Cone-bearing evergreen trees are very characteristic of the forests. Great numbers of alpine species of herbs and shrubs are found on the mountains at and above the timber line. In the alkali regions, where the soil is too full of mineral salts to permit ordinary plants to grow, many kinds of xerophytes, such as the salty sage (*Atriplex*) and the greasewood (*Sarcobatus*), occur. In the southern portion cactuses abound.

PLATE VIII.—Tree Belt along a Stream, Nebraska

The Pacific Slope is characterized by cone-bearing evergreens in great abundance in the mountains and along the foothills. Chief among these in point of size are the redwoods and the "big trees" (Sequoias) (Fig. 32). Oaks are represented by a good many species, several of them evergreen. There are many xerophytes, some of them characteristic of alkali regions; and in Southern California, on account of the long dry season, plants with large roots or rootstocks and bulb-bearing plants (many of them belonging to the lily family) are abundant. The tree yucca (Plate VII) is one of the largest and most interesting xerophytic plants of North America.

CHAPTER XXVI

PARASITES, ENSLAVED PLANTS, MESSMATES, CARNIVOROUS PLANTS

404. Parasites. — A little was said in Chapter IV about parasitic plants, and the life history of one of them, the dodder, was briefly outlined ; another, the wheat rust, was discussed in Sects. 310–313. A *parasitic* plant is one which draws its supply of food partially or wholly from another living plant or animal known as the *host*. Some parasites are seed-plants, but a far greater number of species are spore-plants.

405. Half-Parasitic Seed-Plants. — Half-parasites or partial parasites are those which take a portion of their food (or of raw materials to make food) from their host and manufacture the rest for themselves. Usually they take mainly the newly absorbed soil-water from the host and do their own starch-making by combining the carbonic acid gas, which they absorb through their leaves, with the water stolen by the parasitic roots or *haustoria* imbedded in the wood of the host. Evidently the needed water may just as well be taken from the underground parts of the host as from the upper portions, and accordingly many half-parasites are parasitic on roots. This is the case with many of the beautiful false foxgloves (*Gerardia*), with the painted-cup (*Castillea*), and some species of bastard toad-flax (*Comandra*) ; see Flora. Usually these root-parasites are not recognized by non-botanical people as parasites at

PLATE IX. — A Cottonwood covered with Mistletoe

all, but in Germany a species common in grain fields [1] and the eyebright, which abounds in grass fields, are respectively known as "hunger" and "milk-thief," from the injury they do to the plants on which they fasten themselves. The mistletoe is a familiar example of a half-parasite, which roots on branches (Plate IX). Among the scanty belts of cottonwood trees along streams in New Mexico it is necessary to lop off the mistletoe every year to give the tree any chance to grow. Half-parasites may be known from plants that are fully parasitic by having green or greenish foliage, while complete parasites have no chlorophyll and so are not at all green.

406. Wholly Parasitic Seed-Plants. — These are so nearly destitute of the power of assimilation that they must rob other plants of all needed food or die of starvation. Some, like the cancer-root (see Flora), are root-parasites; others, like the dodder, are parasitic on stems above ground. The most dependent species of all, such as the flax-dodder, can live on only one kind of host, while the coarse orange-stemmed dodder,[2] which is common all over the central and the northeastern states, grows freely on many kinds of plants, from golden-rods to willows.

407. Parasitic Cryptogams. — The wheat rust (Sect. 310) affords an excellent example of the relations between parasitic fungi and their hosts. The illustration showing the potato blight escaping from a stoma of the potato leaf (Fig. 191) shows plainly one way in which a microscopic parasite finds its way out of the tissues of the host-plant to ripen and scatter its spores.

[1] *Alectorolophus hirsutus.*
[2] *Cuscuta Gronovii.*

Perhaps the most interesting, certainly to us the most practically important, cases of parasitism are those in which the bodies of animals, and especially of men, are attacked by parasitic plants. Bacilli and other bacteria of many species (Sect. 263) are among the commonest parasites which use the bodies of animals as hosts, and two or three examples will serve to illustrate how they find a lodgment in the host.

Rich garden soil, the dust of stables, and a good many other sources often contain immense numbers of a bacillus[1] which causes lockjaw. A man in cleaning harness scratches his hand with a buckle, introduces the bacilli into his system, and is soon taken with an attack of lockjaw. Sewage water often swarms with the bacilli of typhoid fever[2] (Fig. 174). The people in a city drink unfiltered water from a river into which sewage has been allowed to run higher up stream, the bacilli multiply at a rapid rate in the intestines of those who have drunk the water, and many of them are taken sick with typhoid fever. The phlegm expectorated by consumptive patients is full of the consumption bacillus;[3] this phlegm becomes dried up on floors, streets, or sidewalks, it is breathed by every one in the form of fine dust, and in the lungs of many who breathe it colonies of the bacillus are formed and the disease (consumption) becomes established in these persons.

408. Enslaved Plants. — Cases in which one kind of plant is useful in procuring food (or the raw materials of food) for another kind are quite common.

The relations on which algæ and fungi live together in

[1] Bacillus tetani. [2] Bacillus typhi. [3] Bacillus tuberculosis.

the form of lichens have already been described (Sect. 331). It is not correct to describe the condition of such algæ as slavery if the term is meant to imply that they derive no benefit from the association. Perhaps serfdom is a

FIG. 236. — Roots of Red Clover with Tubercles.

l, sections of ascending branches ; *b*, enlarged base of stem ; *t*, root-tubercles containing bacteria.

more suitable word, though it is not the term used by botanists. At all events, the alga is enclosed within a network of fungus hyphæ from which it cannot readily escape, and there does most of the work of the lichen, including all of the manufacture of food from carbon dioxide.

409. Messmates.[1] — Plants of very diverse character, which live most intimately together to the advantage of both parties, may be called *messmates*, since in some fashion or other they divide the food supply between them.

FIG. 237. — Common Pitcher-Plant.[2]
At the right one of the pitcher-like leaves is shown in cross-section.

Bacteria live in colonies enclosed in root-tubercles on the roots of certain plants, for instance, beans, peas, lupines, vetches, and clover (Fig. 236), and render the greatest service to the plant to which the roots belong, from which they also derive food and shelter. Such plants do not develop root-tubercles and will not grow well in sterilized soil, that is, soil in which the bacteria have been killed by baking. It is found that the bacteria serve to change nitrogen taken from the air of the soil into nitric acid, which is a most important ingredient in the manufacture of proteids.

Many trees, for example, oaks, beeches, and the cone-

[1] This term is borrowed from the zoölogists as a much simpler one than *symbionts* to express the relation variously known as *symbiosis*, *commensalism*, or *mutualism*.

[2] *Sarracenia purpurea.*

FIG. 238. — Sundew (*Drosera rotundifolia*).

bearing evergreens, and a considerable number of herbaceous plants, such as the Indian pipe (*Monotropa*, Plate V), are covered with a growth of fungus hyphæ (Sect. 307).

FIG. 239. — Blade of Leaf of Sundew. (Somewhat magnified.)

This growth completely surrounds the young, active tips of all the roots and the threads of the *mykorhiza*, as it is called, seem to do the work of root-hairs.

410. Carnivorous Plants. — In the ordinary pitcher-plants (Fig. 237) the leaf appears in the shape of a more or less hooded pitcher. These pitchers are usually partly filled with water, and in this water very many drowned and decaying insects are commonly to be found. The insects have flown or crawled into the pitcher, and, once inside, have been unable to escape on account of the dense growth of bristly hairs about the mouth, all pointing inward and downward. How much the common American pitcher-plants depend for nourishment on the drowned insects in the pitchers is not definitely known, but it is certain that some of the tropical species require such food.[1]

FIG. 240. — Leaves of Sundew. (Somewhat magnified.)

The one at the left has all its tentacles closed over captured prey; the one at the right has only half of them thus closed.

In other rather common plants, the sundews, insects are

[1] Where the *Sarracenia* is abundant it will be found interesting and profitable to make a careful class study of its leaves. See Geddes, *Chapters in Modern Botany*, Chapters I and II.

caught by a sticky secretion which proceeds from hairs on the leaves. In one of the commonest sundews the leaves consist of a roundish blade, borne on a moderately long petiole. On the inner surface and round the margin of the blade (Fig. 239) are borne a considerable number of short bristles, each terminating in a knob which is covered with a clear, sticky liquid. When a small insect touches one of the sticky knobs, he is held fast and the hairs at once begin to close over him, as shown in Fig. 240. Here he soon dies and then usually remains for many days, while the leaf pours out a juice by which the soluble parts of the insect are digested. The liquid containing the digested portions is then absorbed by the leaf and contributes an important part of the nourishment of the plant, while the undigested fragments, such as legs, wing-cases, and so on, remain on the surface of the leaf or may drop off after the hairs let go their hold on the captive insect.

FIG. 241. — Venus Flytrap.

In the Venus flytrap, which grows in the sandy regions of eastern North Carolina, the mechanism for catching insects is still more remarkable. The leaves, as shown in

Fig. 241, terminate in a hinged portion which is surrounded by a fringe of stiff bristles. On the inside of each half of the trap grow three short hairs. The trap is so sensitive that when these hairs are touched it closes with a jerk and very generally succeeds in capturing the fly or other insect which has sprung it. The imprisoned insect then dies and is digested, somewhat as in the case of those caught by the sundew, after which the trap reopens and is ready for fresh captures.

411. Object of catching Animal Food. — It is easy to understand why a good many kinds of plants have taken to catching insects and absorbing the digested products. Carnivorous, or flesh-eating, plants belong usually to one of two classes as regards their place of growth ; they are bog-plants or air-plants. In either case their roots find it difficult to secure much nitrogen-containing food, that is, much food out of which proteid material can be built up. Animal food, being itself largely proteid, is admirably adapted to nourish the growing parts of plants, and those which could develop insect-catching powers would stand a far better chance to exist as air-plants or in the thin, watery soil of bogs than plants which had acquired no such resources.

CHAPTER XXVII

HOW PLANTS PROTECT THEMSELVES FROM ANIMALS

412. Destruction by Animals. — All animals are supported directly or indirectly by plants. In some cases the animal secures its food without much damaging the plant on which it feeds. Browsing on the lower branches of a tree may do it little injury, and grazing animals, if not numerous, may not seriously harm the pasture on which they feed. Fruit-eating animals may even be of much service by dispersing seeds (Sect. 453). But seed-eating birds and quadrupeds, animals which, like the hog, dig up fleshy roots, rootstocks, tubers or bulbs, and eat them, or animals which, like the sheep, graze so closely as to expose the roots of grasses or even of forest trees to be parched by the sun, destroy immense numbers of plants. So too with wood-boring and leaf-eating insects, and snails, which consume great quantities of leaves.

413. Some Modes of Protection from Animals. — Many of the characteristics of plants may be wholly or partly due to adaptations for protective purposes, while in particular cases we cannot be sure of the fact. Perching on lofty rocks or on branches of trees, burying the perennial part (bulb, rootstock, etc.) underground, growing in dense masses, like a canebrake or a thicket of blackberry bushes; all such habits of plants may be partly or altogether valuable to the plant as means of avoiding the attacks of animals, but this cannot be proved. On the other hand,

there are plenty of instances of structures, habits, or accumulations of stored material in their tissue which plants seem to have acquired mainly or entirely as means of defense. Some of the most important are:

(1) The habit of keeping a bodyguard of ants.
(2) Mimicking the appearance of dangerous or uneatable plants, or imitating pebbles or earth, so that they may be overlooked.
(3) Forming tough, corky, woody, limy or flinty and therefore nearly uneatable tissue.
(4) Arming exposed parts with cutting edges, sharp or stinging hairs, prickles, or thorns.
(5) Accumulating unpleasant or poisonous substances in exposed parts.

414. Ant-Plants. — Some ants live on vegetable food, but most of them eat only animal food, and these latter are extremely voracious. It has been estimated by a careful scientist, an authority on this subject, that the ants of a single nest sometimes destroy as many as one hundred thousand insects in a day. The Chinese orange-growers in the Province of Canton have found how useful ants may be as destroyers of other insects, and so they place ant nests in the orange trees and extend bamboos across from one tree to another, to serve as bridges for the ants to travel on.

Certain tropical trees, in order to insure protection by ants, offer them especial inducements to establish colonies on their trunks and branches. The attractions which are offered to ants by various kinds of trees differ greatly. One of the most interesting adaptations is that of an acacia[1] (Fig. 242), which furnishes little growths at the ends of the leaflets which serve as ant food. These little

[1] *A. sphaerocephala.*

growths are known from their discoverer as Belt's bodies. The ants bore holes into the large hollow stipular thorns shown in the figure, live in these thorns, feed on the Belt's bodies, and protect the acacia from insect and other enemies. A nectary on the leaf furnishes additional food to the ant inhabitants of the tree. A great multitude of plants, some of them herbs, offer more or less important

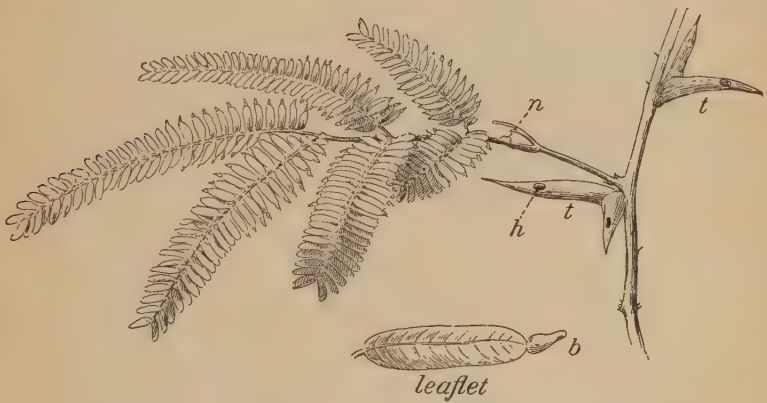


FIG. 242. — An Ant-Plant (*Acacia*).

t, thorns; *h*, hole in thorn; *n*, nectary; *b*, Belt's body on tip of leaflet.

inducements to attract ant visitors; the species which are known to do this number over three thousand.

415. Plants which mimic Plants or Other Objects. — Instances of mimicry of protected plants by unprotected species are not very common. One of the best-known cases is that of the dead-nettle, which is so called because it looks like the stinging nettle, though it is perfectly harmless. Some South African plants (*Kleinias*) appear to mimic pebbles. Certain Mesembryanthemums of the

same region can hardly be distinguished from the earth in which they grow.

416. Plants of Uneatable Texture. — Whenever tender and juicy herbage is to be had, plants of hard and stringy texture are left untouched. The flinty-stemmed scouring-rushes (*Equisetum*, Sect. 361) and the dry, tough rushes are familiar examples of uneatable plants of damp soil. In pastures there grow such perennials as the bracken fern and the hardhack of New England and the ironweed and vervains of the Central States, which are so harsh and woody that the hungriest browsing

FIG. 243. — Spiny Leaves of Barberry.

animal is rarely, if ever, seen to molest them. Still other plants, like the knotgrass and cinquefoil of our dooryards, are doubly safe, from their growing so close to the ground as to be hard to graze and from their woody and unpalatable nature. The date-palm (which can easily be raised from the seed in the schoolroom or the laboratory) is an excellent instance of the same uneatable quality, found in a tropical or sub-tropical plant.

417. Plants with Weapons for Defense.[1] — Multitudes of plants, which might otherwise have been subject to the attacks of grazing or browsing animals, have acquired what have with reason been called weapons. Shrubs and trees not infrequently produce sharp-pointed branches, familiar in our own crab-apple, wild plum, thorn trees, and above all in the honey locust (Fig. 34), whose formidable thorns often branch in a very complicated manner.

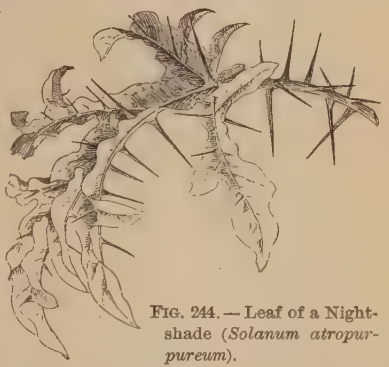


FIG. 244. — Leaf of a Nightshade (*Solanum atropurpureum*).

Thorns, which are really modified leaves, are very perfectly exemplified in the barberry (Fig. 243). It is much commoner to find the leaf extending its midrib or its veins out into spiny points, as the thistle does, or bearing spines or prickles on its midrib, as is the case with the nightshade shown in Fig. 244, and with so many roses. Prickles, which are merely hard, sharp-pointed projections from the epidermis, are of too common occurrence to need illustration.

Stipules are not infrequently found occurring as thorns, and in our common locust (Fig. 246) the bud, or the very young shoot which proceeds from it, is admirably protected by the jutting thorn on either side.

418. Pointed, Barbed, and Stinging Hairs. — Needle-pointed hairs are an efficient defensive weapon of many plants. Sometimes these hairs are roughened, like those

[1] See Kerner and Oliver's *Natural History of Plants*, Vol. I, p. 430.

of the bugloss (Fig. 247, *b*); sometimes they are decidedly barbed. If the barbs are well developed they may cause the hairs to travel far into the flesh of animals and cause intense pain. In the nettle (Fig. 247, *a*) the hairs are efficient stings, with a brittle tip, which on breaking off

FIG. 245. — *Euphorbia splendens*. The spines are dead and dry stipules.

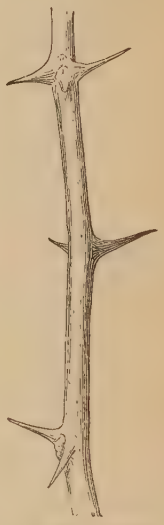


FIG. 246. — Thorn Stipules of Locust.

exposes a sharp, jagged tube full of irritating fluid. These tubular hairs, with their poisonous contents, will be found sticking in the skin of the hand or the face after incautious contact with nettles, and the violent itching which follows is only too familiar to most people.

419. Cutting Leaves. — Some grasses and sedges are generally avoided by cattle because of the sharp-cutting edges of their leaves, which will readily slit the skin of one's hand if they are drawn rapidly through the fingers. Under the microscope the margins of such leaves are seen to be regularly and thickly set with sharp teeth like those of a saw (Fig. 247, *c*, *d*).

420. Weapons of Desert Plants. — In temperate regions, where vegetation is usually abundant, such moderate means of protection as have just been described are generally sufficient to insure the safety of the plants which have developed them. But in desert or semi-desert regions the

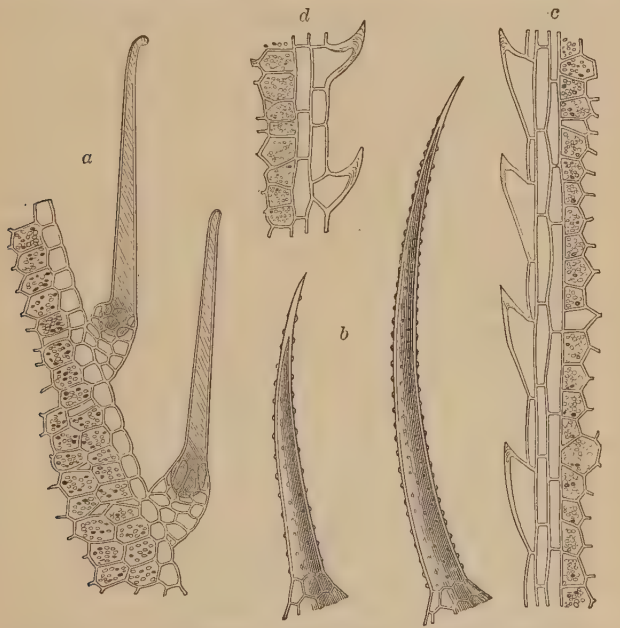


FIG. 247. — Stinging Hairs and Cutting Leaves. (All much magnified.)
a, stinging hairs on leaf of nettle; *b*, bristle of the bugloss; *c*, barbed margin of a leaf of sedge; *d*, barbed margin of a leaf of grass.

extreme scarcity of plant life exposes the few plants that occur there to the attacks of all the herbivorous animals that may encounter them. Accordingly, great numbers of desert plants are characterized by nauseating or poisonous qualities or by the presence of astonishingly developed thorns, while some combine both of these means of defense.

421. Offensive or Poisonous Plants. — A disgusting smell is one of the common safeguards which keep plants from being eaten. The dog fennel (Fig. 227), the hound's-tongue (*Cynoglossum*), the Martynia, and the tomato-plant are common examples of rank-smelling plants which are offensive to most grazing animals and so are let alone by them. Oftentimes, as in the case of the jimson weed (*Datura*), the tobacco-plant, and the poison hemlock (*Conium*), the smell serves as a warning of the poisonous nature of the plant.

A bitter, nauseating, or biting taste protects many plants from destruction by animals. Buckeye, horse-chestnut, and maple twigs and leaves are so bitter that browsing animals and most insects let them alone. Tansy, ragweed, boneset, southernwood, and wormwood are safe for the same reason. The nauseous taste of many kinds of leaves and stems, such as those of the potato, and the fiery taste of pepper-corns, red peppers, mustard, and horse-radish, make these substances uneatable for most animals. Probably both the smell and the taste of onions serve to insure the safety of the bulbs from the attacks of most grubs, and the hard corm of the jack-in-the-pulpit (*Arisæma*) (Frontispiece) is carefully let alone on account of the blistering nature of its contents.

Poisonous plants are usually shunned by grown-up animals, though the young ones will sometimes eat such plants and may be killed by them. Almost any part of a poisonous species may contain the poison characteristic of the plant, but, for obvious reasons, such substances are especially apt to be stored in the parts of the plant where its supply of reserve food is kept.

CHAPTER XXVIII

ECOLOGY OF FLOWERS

422. Topics of the Chapter. — The ecology of flowers is concerned mainly with the means by which the transference of pollen or *pollination* is effected, and with the ways in which pollen is kept away from undesirable insect visitors and from rain.

423. Cross-Pollination and Self-Pollination. — It was long supposed by botanists that the pollen of any perfect flower needed only to be placed on the stigma of the same flower to insure satisfactory fertilization. But in 1857 and 1858 the great English naturalist, Charles Darwin, stated that certain kinds of flowers were entirely dependent for fertilization on the transference of pollen from one plant to another, and he and other botanists soon extended the list of such flowers until it came to include most of the showy, sweet-scented, or otherwise conspicuous kinds. It was also shown that probably nearly all attractive flowers, even if they can produce some seed when self-pollinated, do far better when pollinated from the flowers of another plant of the same kind.[1] This important fact was established by a long series of experiments on the number and vitality of seeds produced by a flower when treated with its own pollen, or *self-pollinated*, and when

[1] See Darwin's *Cross and Self-Fertilization in the Vegetable Kingdom* (especially Chapters I and II).

treated with pollen from another flower of the same kind, or *cross-pollinated*.[1]

424. Wind-Pollinated Flowers.[2] — It has already been mentioned that some pollen is dry and powdery, and other kinds are more or less sticky. Pollen of the dusty sort is light, and therefore adapted to be blown about by the wind. Any one who has been much in cornfields after the corn has "tasseled" has noticed the pale yellow dusty pollen which flies about when a cornstalk is jostled, and which collects in considerable quantities on the blades of the leaves. Corn is monœcious, but fertilization is best accomplished by pollen blown from the "tassel" (stamens) of one plant being carried to the "silk" (pistils) of another plant. This is well shown by the fact, familiar to every observing farmer's boy, that solitary cornstalks, such as often grow very luxuriantly in an unused barnyard or similar locality, bear very imperfect ears or none at all. The common ragweed, another monœcious plant, is remarkable for the great quantities of pollen which shake off it on to the shoes or clothes of the passer-by, and it is wind-pollinated. So, too, are the monœcious pines, and these produce so much pollen that it has been mistaken for showers of sulphur, falling often at long distances from the woods where it was produced. The pistil of wind-pollinated flowers is often feathery and thus adapted to catch flying pollen-grains (Fig. 248). Other

FIG. 248. — Pistil of a Grass, provided with a Feathery Stigma, adapted for Wind-Pollination.

[1] On dispersion of pollen see Kerner and Oliver, Vol. II, pp. 129–287.
[2] See Miss Newell's *Botany Reader*, Part II, Chapter VII.

characteristics of such flowers are the inconspicuous character of their perianth, which is usually green or greenish, the absence of odor and of nectar, the regularity of the corolla, and the appearance of the flowers before the leaves or their occurrence on stalks raised above the leaves.

Pollen is, in the case of a few aquatic plants, carried from flower to flower by the water on which it floats.

425. Insect-Pollinated Flowers. — Most plants which require cross-pollination depend upon insects as pollen-carriers,[1] and it may be stated as a general fact that the showy colors and markings of flowers and their odors all serve as so many advertisements of the nectar (commonly but wrongly called honey) or of the nourishing pollen which the flower has to offer to insect visitors.

Many insects depend mainly or wholly upon the nectar and the pollen of flowers for their food. Such insects usually visit during any given trip only one kind of flower, and therefore carry but one kind of pollen. Going straight from one flower to another with this, they evidently waste far less pollen than the wind or water must waste. It is therefore clearly advantageous to flowers to develop such adaptations as fit them to attract insect visitors, and to give pollen to the latter and receive it from them.

426. Pollen-Carrying Apparatus of Insects.[2] — Ants and some beetles which visit flowers have smooth bodies, to which little pollen adheres, so that their visits are often of slight value to the flower, but many beetles, all butterflies and moths, and most bees have bodies roughened with scales or hairs which hold a good deal of pollen entangled.

[1] A few are pollinated by snails; many more by humming-birds and other birds.

[2] See Müller's *Fertilization of Flowers*, Part II.

In the common honey-bee (and in many other kinds) the greater part of the insect is hairy, and there are special collecting baskets, formed by bristle-like hairs, on the hind legs (Fig. 249). It is easy to see the load of pollen accumulated in these baskets after such a bee has visited several flowers. Of course the pollen which the bee packs in the baskets and carries off to the hive, to be stored for food, is of no use in pollination. In fact such pollen is in one sense entirely wasted. But since such bees as have these collecting baskets are the most industrious visitors to flowers, they accomplish an immense share of the work of pollination by means of the pollen grains which stick to their hairy coats and are then transferred to other flowers of the same kind next visited by the bee.

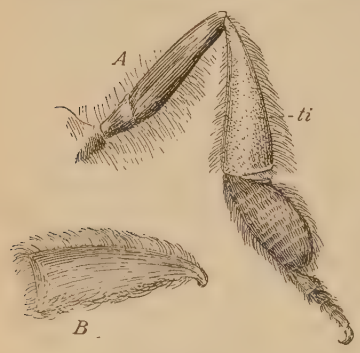


FIG. 249.

A, right hind leg of a honey-bee (seen from behind and within); *B*, the tibia, *ti*, seen from the outside, showing the collecting basket formed of stiff hairs.

427. Nectar and Nectaries. — Nectar is a sweet liquid which flowers secrete for the purpose of attracting insects. After partial digestion in the crop of the bee, nectar becomes honey. Those flowers which secrete nectar do so by means of *nectar glands*, small organs whose structure is something like that of the stigma, situated often near the base of the flower, as shown in Fig. 250. Sometimes the nectar clings in droplets to the surface of the nectar glands; sometimes it is stored in little cavities or pouches

called *nectaries*. The pouches at the bases of columbine petals are among the most familiar of nectaries.

428. Odors of Flowers. — The acuteness of the sense of smell among insects is a familiar fact. Flies buzz about the wire netting which covers a piece of fresh meat or a dish of syrup, and bees, wasps, and hornets will fairly besiege the window screens of a kitchen where preserving is going on. Many plants find it possible to attract as many insect visitors as they need without giving off any scent, but small flowers, like the mignonette, and night-blooming ones, like the white tobacco and the evening primrose, are sweet-scented to attract night-flying moths. It is interesting to observe that the majority of the flowers which bloom at night are white, and that they are much more generally sweet-scented than flowers which bloom during the day. A few flowers are carrion-scented (and purplish or brownish colored) and attract flies.

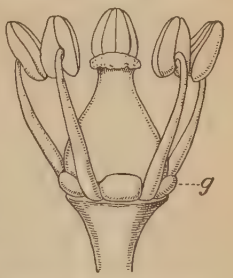


FIG. 250. — Stamens and Pistil of the Grape (magnified), with a Nectar Gland, *g*, between Each Pair of Stamens.

429. Colors of Flowers. — Flowers which are of any other color than green probably in most cases display their colors to attract insects, or occasionally birds. The principal color of the flower is most frequently due to showy petals; sometimes, as in the marsh marigold, it belongs to the sepals; and not infrequently, as in some cornels and Euphorbias (Fig. 245), the involucre is more brilliant and conspicuous than any part of the flower strictly so called.

Different kinds of insects appear to be especially attracted by different colors. In general, dull yellow,

brownish, or dark purple flowers, especially if small, seem to depend largely on the visits of flies. Red, violet, and blue are the colors by which bees and butterflies are most readily enticed. The power of bees to distinguish colors has been shown by a most interesting set of experiments in which daubs of honey were put on slips of glass laid on separate pieces of paper, each of a different color, and exposed where bees would find them.[1]

It is certain, however, that colors are less important means of attraction than odors from the fact that insects are extremely near-sighted. Butterflies and moths cannot see distinctly at a distance of more than about five feet, bees and wasps at more than two feet, and flies at more than two and a fourth feet. Probably no insects can make out objects clearly more than six feet away.[2] Yet it is quite possible that their attention is attracted by colors at distances greater than those mentioned.

430. Nectar Guides. — In a large number of cases the petals of flowers show decided stripes or rows of spots, of a color different from that of most of the petal. These commonly lead toward the nectaries, and it is possible that such markings point out to insect visitors the way to the nectaries. Following this course, the insect not only secures the nectar which he seeks, but probably leaves pollen on the stigma and becomes dusted with new pollen, which he carries to another flower.

431. Facilities for Insect Visits. — Regular polypetalous flowers have no special adaptations to make them singly

[1] See Lubbock's *Flowers, Fruits, and Leaves*, Chapter I. On the general subject of colors and odors in relation to insects, see Müller's *Fertilization of Flowers*, Part IV.

[2] See Packard's *Text-Book of Entomology*, p. 260.

accessible to insects, but they lie open to all comers. They do, however, make themselves much more attractive and afford especial inducements in the matter of saving time to flower-frequenting insects by being grouped. This purpose is undoubtedly served by dense flower-clusters, especially by heads like those of the clovers and by the peculiar form of head found in so-called composite flowers, like the sunflower, the bachelor's button, and the yarrow (Fig. 133). In many such clusters the flowers are specialized, some carrying a showy strap-shaped corolla, to serve as an advertisement of the nectar and pollen contained in the inconspicuous tubular flowers (see Plate XI). Irregular flowers probably always are more or less adapted to particular insect (or other) visitors. The adaptations are extremely numerous; — here only a very few of the simpler ones will be pointed out. Where there is a drooping lower petal (or, in the case of a gamopetalous corolla, a lower lip), this serves as a perch upon which flying insects may alight and stand while they explore the flower, as the beetle is doing in Fig. 251. In Fig. 252 one bumblebee stands with his legs partially encircling the lower lip of the dead-nettle flower, while another perches on the sort of grating made by the stamens of the horse-chestnut flower. The honey-bee entering the violet clings to the beautifully bearded portion of the two lateral petals, while it sucks the nectar from the *spur* beneath.

FIG. 251. — A Beetle on the Flower of the Twayblade. (Enlarged three times.)

432. Protection of Pollen from Unwelcome Visitors. — It is usually desirable for the flower to prevent the entrance of small creeping insects, such as ants, which carry little pollen and eat a relatively large amount of it. The means adopted to secure this result are many and curious. In

FIG. 252. — Bees visiting Flowers.

At the left a bumblebee on the flower of the dead nettle; below a similar bee in the flower of the horse-chestnut; above a honey-bee in the flower of a violet.

some plants, as the common catchfly, there is a sticky ring about the peduncle, some distance below the flowers, and this forms an effectual barrier against ants and like insects. Very frequently the calyx tube is covered with hairs, which are sometimes sticky. How these thickets of hairs may appear to a very small insect can perhaps be more easily realized by looking at the considerably

magnified view of the hairs from the outer surface of mullein petals, shown in Fig. 253.[1]

Sometimes the recurved petals or divisions of the corolla stand in the way of creeping insects. In other cases the

FIG. 253. — Branching Hairs from the Outside of the Corolla of the Common Mullein. (Magnified.) *dr*, a gland.

FIG. 254. — A Sphinx Moth, with a Long Sucking-Tube.

throat of the corolla is much narrowed or closed by hairs, or by appendages. Those flowers which have one or more

[1] On protection of pollen, see Kerner and Oliver, Vol. II, pp. 95–109.

sepals or petals prolonged into spurs, like the nasturtium and the columbine, are inaccessible to most insects except those which have a tongue or a sucking-tube long enough to reach to the nectary at the bottom of the spur. The large sphinx moth, shown in Fig. 254, which is a common visitor to the flowers of the evening primrose, is an example of an insect especially adapted to reach deep into long tubular flowers.

A little search among flowers, such as those of the columbine or the foxglove, will usually disclose many which have had the corolla bitten through by bees, which are unable to get at the nectar by fair means or unwilling to take the trouble to do so; and they therefore steal it.

433. Bird-Pollinated Flowers. — Some flowers with very long tubular corollas depend entirely upon birds to carry their pollen for them. Among garden flowers the gladiolus, the scarlet salvia, and the trumpet honeysuckle are largely dependent upon humming-birds for their pollination. The wild balsam or jewel-weed and the trumpet-creeper (Plate X) are also favorite flowers of the humming-bird.

434. Prevention of Self-Fertilization. — Dicœcious flowers are of course quite incapable of self-pollination. Pistillate moncœcious flowers may be pollinated by staminate ones on the same plant, but this does not secure as good seed as is secured by having pollen brought to the pistil from a different plant of the same kind.

In perfect flowers self-pollination would commonly occur unless it were prevented by the action of the essential organs or by something in the structure of the flower. In reality many flowers which at first sight would appear to be designed to secure self-pollination are almost or quite

PLATE X. — Humming Bird visiting Trumpet Creeper

incapable of it. Frequently the pollen from another plant of the same species prevails over that which the flower may shed on its own pistil, so that when both kinds are placed on the stigma at the same time it is the foreign pollen which causes fertilization. But apart from this fact there are several means of insuring the presence of foreign pollen, and only that, upon the stigma, just when it is mature enough to receive pollen tubes.

435. Stamens and Pistils maturing at Different Times. — If the stamens mature at a different time from the pistils, self-pollination is as effectually prevented as though the plant were dicœcious. This unequal maturing or *dichogamy* occurs in many kinds of flowers. In some, the figwort and the common plantain for example, the pistil develops before the stamens, but usually the reverse is the case. The *Clerodendron*,[1] a tropical African flower (Fig. 255), illustrates in a most striking way the development of stamens before the pistil. The insect visitor, on its way to the nectary, can hardly fail to brush against the protruding stamens of the flower in its earlier stage (at *A*), but it cannot deposit any pollen on the stigmas,

FIG. 255. — Flower of *Clerodendron* in Two Stages.

In *A* (earlier stage) the stamens are mature, while the pistil is still undeveloped and bent to one side. In *B* (later stage) the stamens have withered and the stigmas have separated, ready for the reception of pollen.

[1] *C. Thompsoniæ.*

which are unripe, shut together, and tucked aside out of reach. On flying to a flower in the later stage the pollen just acquired will be lodged on the prominent stigmas and thus produce the desired cross-pollination.

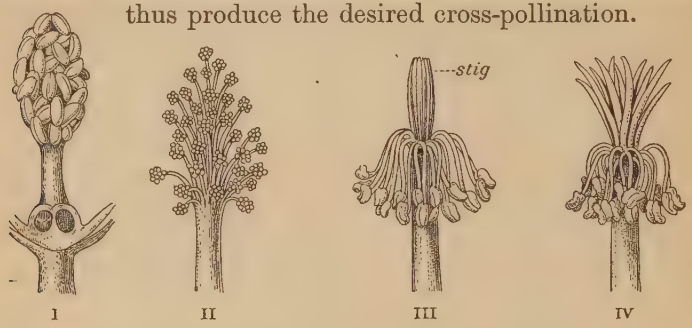


FIG. 256. — Provisions for Cross-Pollination in the High Mallow.

I, essential organs as found in the bud; II, same in the staminate stage, the anthers discharging pollen, pistils immature; III, intermediate stage, *stig*, the united stigmas; IV, pistillate stage, the stigmas separated, stamens withered.

Closely related flowers often differ in their plan of pollination. The high mallow, a plant cultivated for its purplish flowers, which has run wild to some extent, is admirably adapted to secure cross-pollination, since when its stamens are shedding pollen, as in Fig. 256, II, the pistils are incapable of receiving it, while when the pistils are mature, as at IV, the stamens are quite withered. In the common low mallow of our dooryards and waysides insect pollination may occur, but if it does not the curling stigmas finally come in contact with the projecting stamens and receive pollen from them, as is indicated in Fig. 257.

FIG. 257. — Stamens and Pistils of Round-Leafed Mallow. The stigmas curled round among the stamens to admit of self-pollination.

436. Movements of Floral Organs to aid in Pollination. — Besides the slow movements which the stamens and pistil make in such cases as those of the *Clerodendron* and the mallow, already described, the parts of the flower often admit of considerable and rather quick movements to assist the insect visitor to become dusted or smeared with pollen.

In some flowers whose stamens perform rapid movements when an insect enters, it is easy to see how directly

FIG. 258. — Two Flowers of Common Sage, one of them visited by a Bee.

useful the motion of the stamens is in securing cross-pollination. The stamens of the laurel, *Kalmia*, throw little masses of pollen, with a quick jerk, against the body of the visiting insect. Barberry stamens spring up against the visitor and dust him with pollen. The common garden sage matures its anthers earlier than its stigmas. In Fig. 258, *A*, the young flower is seen, visited by a bee, and one anther is shown pressed closely against the side of the bee's abdomen. The stigma, *st*, is hidden within the upper lip of the corolla. In *B*, an older flower, the

anthers have withered and the stigma is now lowered so as to brush against the body of any bee which may enter. A little study of Fig. 259 will make clear the way in which the anthers are hinged, so that a bee strik-

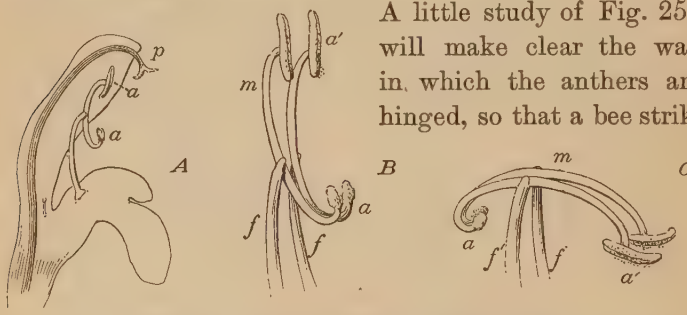


FIG. 259. — Flower and Stamens of Common Sage.

A, *p*, stigma; *a*, anthers; *B*, the two stamens in ordinary position; *f*, filaments; *m*, connective (joining anther-cells); *a′*, anther-cells; *C*, the anthers and connectives bent into a horizontal position by an insect pushing against *a*.

ing the empty or barren anther-lobes, *a*, knocks the pollen-bearing lobes, *a′*, into a horizontal position, so that they will lie closely pressed against either side of its abdomen.

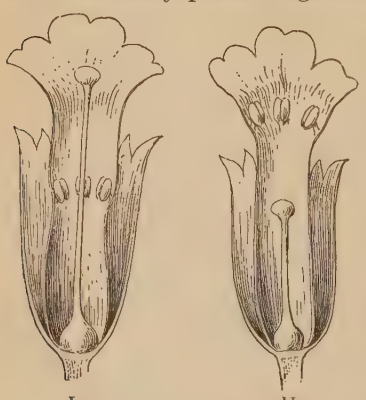


FIG. 260. — Dimorphous Flowers of the Primrose.

I, a long-styled flower; II, a short-styled one.

437. Flowers with Stamens and Pistils Each of Two Lengths. — The flowers of bluets, partridge-berry, the primroses, and a few other common plants secure cross-pollination by having essential organs of two forms (Fig. 260). Such flowers are said to be *dimorphous* (of two forms). In the short-styled flowers, II, the anthers are borne at the top of the corolla tube and the

stigma stands about halfway up the tube. In the long-styled flowers, I, the stigma is at the top of the tube and the anthers are borne about halfway up. An insect pressing its head into the throat of the corolla of II would become dusted with pollen, which would be brushed off on the stigma of a flower like I. On leaving a long-styled flower the bee's tongue would be dusted over with pollen, some of which would necessarily be rubbed off on the stigma of the next short-styled flower that was visited. Cross-pollination is insured, since all the flowers on a plant are of one kind, either long-styled or short-styled, and since the pollen is of two sorts, each kind sterile on the stigma of any flower of similar form to that from which it came.

Trimorphous flowers, with long, medium, and short styles, are found in a species of loosestrife.[1]

438. Studies in Insect Pollination. — The student cannot gather more than a very imperfect knowledge of the details of cross-pollination in flowers without actually watching some of them as they grow, and observing their insect visitors. If the latter are caught and dropped into a wide-mouthed stoppered bottle containing a bit of cotton saturated with chloroform, they will be painlessly killed, and most of them may be identified by any one who is familiar with our common insects. The insects may be observed and classified in a general way into butterflies, moths, bees, flies, wasps, and beetles, without being captured or molested.

Whether these out-of-door studies are made or not, several flowers should be carefully examined and described as regards their arrangements for attracting and utilizing insect visitors (or birds). The following list includes a considerable number of the most accessible flowers of spring and early summer, about which it is easy to get information from books.

[1] See Miss Newell's *Reader in Botany*, Part II, pp. 60–63.

LIST OF INSECT-POLLINATED FLOWERS.[1]

I

1.	Flax	*Linum usitatissimum*	Müll.
2.	Missouri currant	*Ribes aureum*	Müll.
3.	Snowberry	*Symphoricarpus racemosus*	Müll.
4.	Lilac	*Syringa persica*	Müll.
5.	Periwinkle	*Vinca minor*	Müll.
6.	Mignonette	*Reseda odorata*	Müll.
7.	Pansy	*Viola tricolor*	Müll.
8.	Dead nettle	*Lamium album*	Lubbock.
9.	Bleeding heart	*Dicentra* (*Diclytra*) *spectabilis*	Müll.
10.	Columbine	*Aquilegia vulgaris*	Müll.
11.	Monkshood	*Aconitum Napellus*	Müll.

II

12.	Larkspur	*Delphinium tricorne*, *D. Consolida*	Müll.
13.	Herb Robert	*Geranium Robertianum*	Müll.
14.	Pink	*Dianthus* (various species)	Müll.
15.	Fireweed	*Epilobium angustifolium*	Gray.
16.	Nasturtium	*Tropæolum majus*	Newell, Lubbock.
17.	Lily-of-the-valley	*Convallaria majalis*	Müll.
18.	Heal-all	*Prunella vulgaris*	Müll.
19.	Ground ivy	*Nepeta hederacea*	Müll., Newell.
20.	Lousewort	*Pedicularis canadensis*	Müll., Newell.
21.	Snapdragon	*Antirrhinum majus*	Müll.
22.	Iris	*Iris versicolor*	Newell.
23.	Bellflower	*Campanula rapunculoides*	Müll.
24.	Horse-chestnut	*Æsculus Hippocastanum*	Newell.

[1] The plants in this list are arranged somewhat in the order of the complexity of their adaptations for insect pollination, the simplest first. It would be well for each student to take up the study of the arrangements for the utilization of insect visitors in several of the groups above, numbered with Roman numerals. The teacher will find explanations of the adaptations in the works cited by abbreviations at the right. Müll. stands for Müller's *Fertilization of Flowers;* Lubbock, for *British Wild Flowers, considered in Relation to Insects;* Gray, for Gray's *Structural Botany;* and Newell, for Miss Newell's *Outlines of Lessons in Botany*, Part II. Consult also Knuth-Davis' *Handbook of Flower Pollination*, Clarendon Press, Oxford.

III

25.	Yarrow	*Achillea millefolium*	Müll.
26.	Oxeye daisy	*Chrysanthemum Leucanthemum*	Müll.
27.	Dandelion	*Taraxacum officinale*	Müll., Newell.

IV

28.	Barberry	*Berberis vulgaris*	Lubbock.
29.	Mountain laurel	*Kalmia latifolia*	Gray.

V

30.	White clover	*Trifolium repens*	Müll.
31.	Red clover	*Trifolium pratense*	Müll.
32.	Locust	*Robinia Pseudo-Acacia*	Gray.
33.	Wisteria	*Wisteria sinensis*	Gray.
34.	Vetch	*Vicia Cracca*	Müll.
35.	Pea	*Pisum sativum*	Müll.
36.	Bean	*Phaseolus vulgaris*	Gray.
37.	Ground-nut	*Apios tuberosa*	Gray.

VI

38.	Partridge-berry	*Mitchella repens*	Gray.
39.	Primrose	*Primula grandiflora, P. officinalis*	Lubbock.
40.	Loosestrife	*Lythrum Salicaria*	Gray.

VII

41.	Milkweed	*Asclepias syriaca*	Müll., Newell.

VIII

42.	Lady's-slipper	*Cypripedium acaule*	Newell.

439. Cleistogamous Flowers. — In marked contrast with such flowers as those discussed in the preceding sections, which bid for insect visitors or expose their pollen to be blown about by the wind, are certain flowers which remain closed even during the pollination of the stigma. These flowers are called cleistogamous and of course are not

cross-pollinated. Usually they occur on plants which also bear flowers adapted for cross-pollination, and in this

FIG. 261. — A Violet, with Cleistogamous Flowers.

The objects which look like flower-buds are cleistogamous flowers in various stages of development. The pods are the fruit of similar flowers. The plant is represented as it appears in late July or August, after the ordinary flowers have disappeared.

case the closed flowers are much less conspicuous than the others, yet they produce much seed. Every one knows the ordinary flowers of the violet, but most people

FIG. 262. — Protection of Pollen from Moisture.

At the left herb Robert and sweet scabious in sunny weather; at the right the same flowers during rain.

do not know that violets very generally, after the blossoming season (of their showy flowers) is over, produce many cleistogamous flowers, as shown in Fig. 261.

440. Protection of Pollen from Rain. — Pollen is very generally protected from being soaked and spoiled by rain or dew either by the natural position of the flower preventing rain from entering, as in the case with most gamopetalous, nodding flowers, or by changes in the position of the flower, and by its opening in sunny weather and closing at night or during rain. Sometimes the flower both changes its position and closes, as is the case with the herb Robert and the sweet scabious (Fig. 262). The adaptations of flowers to protect their pollen from becoming wet can best be understood by actually examining the same flower in sunshine and during rain.

PLATE XI. — Aster and Golden-Rod

CHAPTER XXIX

HOW PLANTS ARE SCATTERED AND PROPAGATED

441. Means of Propagation among Cryptogams. — Some of the highest cryptogams, as the ferns, spread freely by means of their creeping rootstocks, and the gardener who wishes quickly to get large, strong ferns often finds it the easiest plan to cut to pieces and reset the rootstocks of a well-established plant. Some ferns also grow readily from bulblets produced on the fronds. In the walking fern the tip of the frond roots and begins a new plant. Most flowerless plants, however, are reproduced either by a process of fission, as in *Pleurococcus* (Sect. 278), *Diatoms* (Sect. 271), *Bacteria* (Sect. 266), and many other groups, or by some kind of spore (Sect. 259). The spore is usually so small an object that it is carried with the greatest ease by currents of water or of air, as the case may be, so that it is no sooner liberated than it is swept away, often to a very distant locality, where it can grow and not be interfered with by too many neighbors of its own kind. Thus spores of any of the marine algæ are certainly carried thousands of miles by ocean currents, and spores of tree ferns may be blown great distances from one oceanic island to another, or the spore contents of a puff-ball might travel on the wind half the breadth of a continent.

442. Dispersal of Seed-Plants by Roots and Rootstocks. — The student has learned (in Chapters IV and V) that roots and underground stems of many kinds may serve to

reproduce the plant. Either roots or rootstocks may travel considerable distances horizontally in the course of their growth and then shoot up and produce a new plant, which later becomes independent of the parent. The sedges (Fig. 43) are excellent illustrations of this process, and trees like the common locust and the silver-leaf poplar become great nuisances in the neighborhood of lawns and gardens by sending up sprouts in many places. When growing wild, such trees as these depend largely upon spreading by the roots to keep up their numbers.[1]

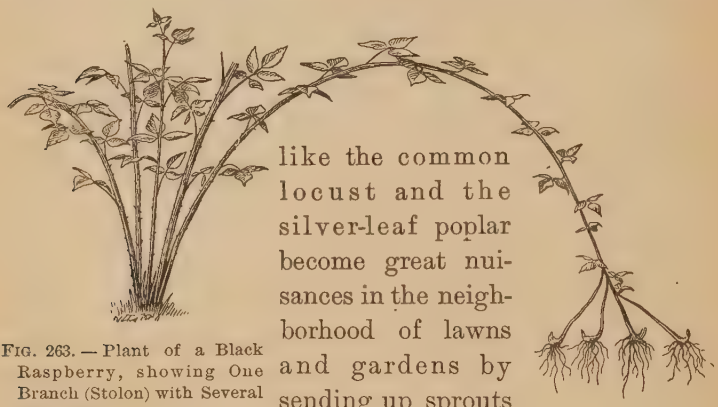


FIG. 263. — Plant of a Black Raspberry, showing One Branch (Stolon) with Several Tips rooting.

443. Dispersal of Seed-Plants by Branches. — There is a shrub of the Honeysuckle Family,[2] common in the northern woods, which is quite generally known as hobble-bush, or witch-hobble, and sometimes as trip-toe. This is because the branches take root at the end and so form loops which catch the foot of the passer-by. The same habit of growth is found in the raspberry-bush (Fig. 263), in one species of strawberry-bush (*Evonymus*), and some other shrubs. Many herbs like the strawberry-plant and the cinquefoil send

[1] See Beal's *Seed Dispersal*, Chapters II and III.

[2] *Viburnum lantanoides.*

out long, leafless runners which root at intervals and so propagate the plant, carrying the younger individuals off to a considerable distance from the parent plant.

Living branches may drop freely from the tree and then take root and grow, after having been blown or been carried by a brook or river to a favorable spot, perhaps hundreds of yards away. The so-called snap-willows lose many live twigs under conditions suitable for starting new trees.

A slightly different mode of dispersal from that of the raspberry is one in which buds separate from the plant and serve to propagate it. In the bladderwort (Fig. 264), at the close of the growing season, the terminal buds are released by the decay of the stem and sink to the bottom of the water in which the plants live, there to remain dormant until spring. Then each bud starts into life and gives rise to a new individual.

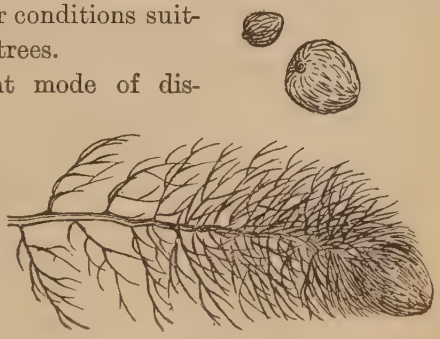


FIG. 264. — A Free Branch and Two Buds of Bladderwort.

444. Dispersal of Seed-Plants by Bulblets. — Almost every farmer's boy knows what "onion-sets" are. These are little bulbs, produced at the top of a naked flower-stalk or scape by some kinds of onions which do not usually flower or bear seed. Tiger-lilies produce somewhat similar bulblets in the axils of the leaves, and there is a large number of species, scattered among numerous families of plants, all characterized by the habit of producing

bulblets. When mature the bulblets fall off readily, and if they find lodgment on unoccupied soil, they grow readily into new plants. Sometimes they are carried moderate distances by wind or water, and if the ground slopes, they may easily roll far enough to get started in new places.

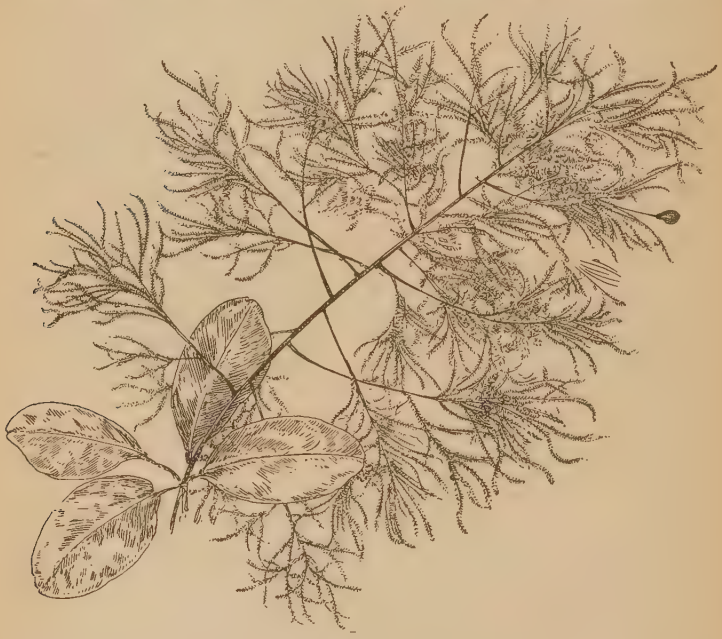


FIG. 265. — Fruit of Smoke-Tree (*Rhus Cotinus*).

Only one pedicel bears a fruit, all the others are sterile, branched, and covered with plumy hairs.

445. Dispersal of Seeds. — Seeds are not infrequently scattered by apparatus by which the plant throws them about. More commonly, however, they depend upon other agencies, such as wind, water, or animals, to carry them. Sometimes the transportation of seeds is due to

the structure of the seeds themselves, sometimes to that of the fruit in which they are enclosed; the essential point is to have transportation to a long distance made as certain as possible, to avoid overcrowding.

446. Explosive Fruits. — Some dry fruits burst open when ripe in such a way as to throw their seeds violently about. Interesting studies may be made, in the proper season, of the fruits of the common blue violet, the pansy, the wild balsam, the garden balsam, the crane's-bill, the herb Robert, the witch-hazel, the Jersey tea, and some other common plants. The capsule of the tropical American sand-box tree bursts open when thoroughly dry with a noise like that of a pistol shot.

FIG. 266. — Fruits of Linden, with a Bract joined to the Peduncle and forming a Wing.

447. Winged or Tufted Fruits and Seeds. — The fruits of the ash, box-elder, elm, maple (Fig. 169), and many other trees, are provided with an expanded membranous wing. Some seeds, as those of the catalpa and the trumpet-creeper, are similarly appendaged. The fruits of the dandelion, the thistle (Fig. 267), the fleabane, and many other plants of the group to which these belong, and the seeds of the willow, the milkweed (Fig. 267), the willow-herb, and other plants, bear a tuft of hairs.

The student should be able, from his own observations on the falling fruits of some of the trees and other plants above mentioned, to answer such questions as the following:

Fig. 267. — Winged Fruits of Thistle; Winged Seeds of Milkweed.

What is the use of the wing-like appendages? of the tufts of hairs?

Which set of contrivances seems to be the more successful of the two in securing this object?

What particular plant of the ones available for study seems to have attained this object most perfectly?

What is one reason why many plants with tufted fruits, such as the thistle and the dandelion, are extremely troublesome weeds?

A few simple experiments, easily devised by the student, may help him to find answers to the questions above given.[1]

448. Tumbleweeds. — Late in the autumn, fences, particularly on prairie farms that are not carefully tilled, often serve as lodging-places for immense numbers of certain dried-up plants known as tumbleweeds. These blow about over the level surface until the first snow falls and

[1] See Kerner and Oliver, Vol. II, pp. 833–875; also Beal's *Seed Dispersal.*

even after that (Fig. 269), often traveling for many miles before they come to a stop, and rattling out seeds as they go. Some of the commonest tumbleweeds are the Russian thistle (Fig. 268), the pigweed (*Amaranthus græcizans*, Fig. 269), tickle-grass (Fig. 270), and a familiar pepper-grass (*Lepidium*). In order to make a successful tumbleweed, a plant must be pretty nearly globular in form when fully grown and dried, must be tough and light, must break off near the ground, and drop its seeds only a few at a time as it travels. A single plant of Russian thistle is sometimes as much as three feet high and six feet in diameter and carries not less than two hundred thousand seeds.

Fig. 268. — Russian Thistle.

449. Many-Seeded Pods with Small Openings. — There are many fruits which act somewhat like pepper-boxes. The capsule of the poppy is a good instance of this kind, and the fruit of lily, monkshood (Fig. 168), columbine, larkspur, and jimson weed (Fig. 271) acts in much the same way. Clamping the dry peduncle of any one of these ripe fruits, so as to hold it upright above the table-top, and then swinging it back and forth, will readily show its efficiency in seed dispersal.

450. Study of Transportation by Water. — Nothing less than a long series of observations by the pond-margin and the brookside will suffice to show how general and impor-

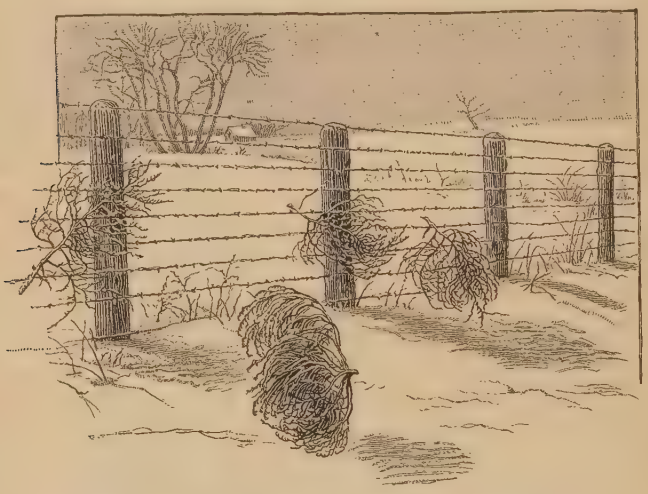


FIG. 269. — Tumbleweeds[1] lodged against a Wire Fence in Winter.

tant is the work done by water in carrying the seeds of aquatics. An experiment will, however, throw some light on the subject.

EXPERIMENT XL

Adaptation for Transportation by Water. — Collect fruits of as many aquatic, semi-aquatic, or riverside and brookside species of plants as possible, place them on shallow pans of water and notice what proportion of all the kinds studied will float. Leave them twenty-four hours or more and see whether all the kinds that floated at first are still afloat. Some desirable fruits for this experiment

[1] *Amaranthus græcizans.*

are: aquatic grasses, rushes and sedges, polygonums, water-dock, bur-reed, arrowhead, water-plantain, pickerel-weed, alder, button-bush, water-parsnip (*Sium*), water-hemlock (*Cicuta*), water penny-wort (*Hydrocotyle*).

451. Distances traversed by Floating Seeds. — Ocean currents furnish transportation for the longest journeys that are made by floating seeds. It is a well-known fact that cocoa-palms are among the first plants to spring up on newly formed coral islands. The nuts from which these palms grew may readily have floated a thousand miles or more without injury. On examining a cocoanut with the fibrous husk attached, just as it fell from the tree, it is easy to see how well this fruit is adapted for transportation by water. There are altogether about a hundred drifting fruits known, one (the Maldive nut) reaching a weight of twenty to twenty-five pounds.

FIG. 270. — Panicle of Tickle-Grass, a Common Tumbleweed.

452. Burs. — A large class of fruits is characterized by the presence of hooks on the outer surface. These are sometimes outgrowths from the ovary, sometimes from

the calyx, sometimes from an involucre. Their office is to attach the fruit to the hair or fur of passing animals. Often, as in sticktights (Fig. 272), the hooks are comparatively weak, but in other cases, as in the cocklebur (Fig. 272), and still more in the Martynia, the fruit of which in the green condition is much used for pickles, the hooks are exceedingly strong. Cockleburs can hardly be removed from the tails of horses and cattle, into which

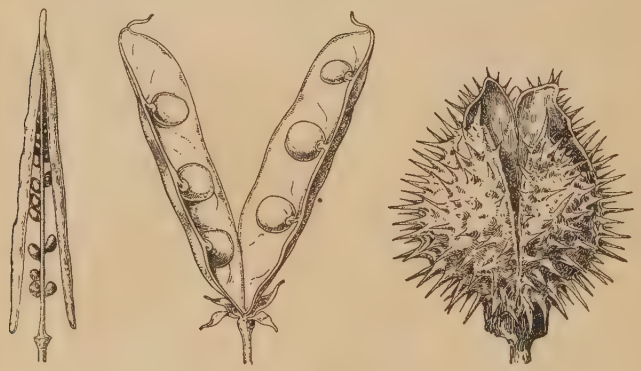


FIG. 271. — Three Fruits adapted for Dispersal by the Shaking Action of the Wind. I, celandine; II, pea; III, jimson weed (*Datura*).

they have become matted, without cutting out all the hairs to which they are fastened.

A curious case of distribution of this kind occurred in the island of Ternate, in the Malay Archipelago. A buffalo with his hair stuck full of the needle-like fruits of a grass[1] was sent as a present to the so-called King of Ternate. Scattered from the hair of this single animal, the grass soon spread over the whole island.

[1] *Andropogon acicularis.*

Why do bur-bearing plants often carry their fruit until late winter or early spring?

What reason can be given for the fact that the burdock, the cocklebur, the beggar's-ticks, the hound's-tongue, and many other common burs, are among the most persistent of weeds?

453. Uses of Stone Fruits and of Fleshy Fruits to the Plant. — Besides the *dry fruits*, of which some of the principal kinds have been mentioned, there are many kinds

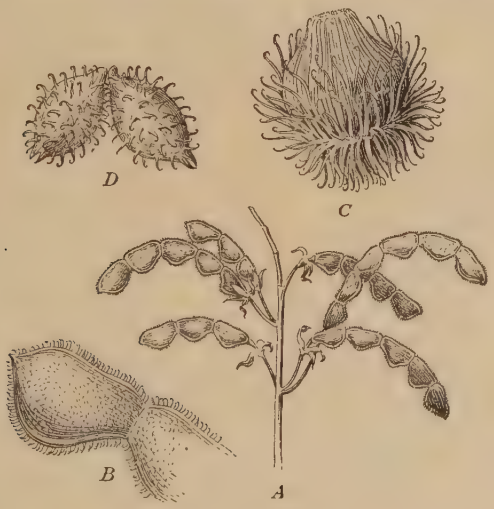


FIG. 272. — Burs.

A, sticktights; *B*, sticktights, two segments, magnified; *C*, burdock; *D*, cocklebur.

of *stone fruits and other fleshy fruits* (Sects. 242–247). Of these the great majority are eatable by man or some of the lower animals, and oftentimes the amount of sugar and other food material which they contain is very considerable. It is a well-recognized principle of botany, and

of zoölogy as well, that plants and animals do not make unrewarded outlays for the benefit of other species. Evidently the pulp of fruits is not to be consumed or used

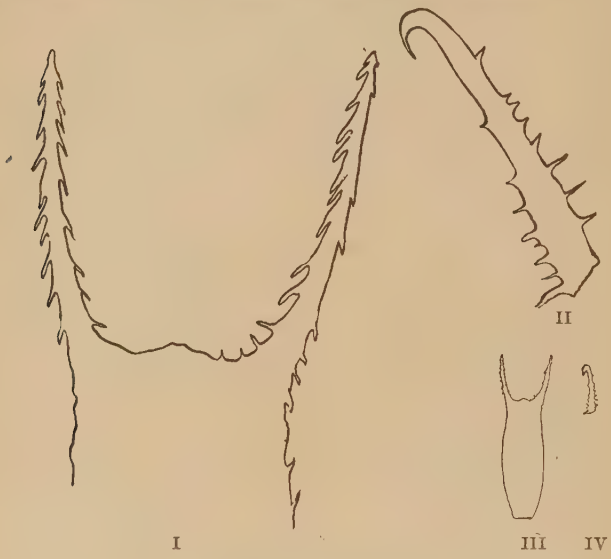


FIG. 273. — Barbs and Hooks of Burs.

I, barbed points from fruit of beggar's-ticks, magnified eleven times; II, hook of cocklebur, magnified eleven times; III, beggar's-ticks fruit, natural size; IV, cocklebur hook, natural size.

as food by the plant itself or (in general) by its seeds. It is worth while, therefore, for the student to ask himself some such questions as these:[1]

(1) Why is the pulp of so many fruits eatable?

(2) Why are the seeds of many pulpy fruits bitter or otherwise unpleasantly flavored, as in the orange?

(3) Why are the seeds or the layers surrounding the

[1] See Kerner and Oliver's *Natural History of Plants*, Vol. II, pp. 442–450.

seeds of many pulpy fruits too hard to be chewed, or digested, as in the date and the peach?

(4) Why are the seeds of some pulpy fruits too small to be easily chewed, and also indigestible, as in the fig and the currant?

(5) Account for the not infrequent presence of currant bushes or asparagus plants in such localities as the forks of large trees, sometimes at a height of twenty, thirty, or more feet above the ground (Fig. 274).

Careful observation of the neighborhood of peach, plum, cherry, or apple trees at the season when the fruit is ripe and again during the following spring, and an examination into the distribution of wild apple or pear trees in pastures where they occur, will help the student who can make such observations to answer the preceding questions. So, too, would an examination of the habits of fruit-eating quadrupeds and of the crop and gizzard of fruit-eating birds during the season when the fruits upon which they feed are ripe.

FIG. 274. — Red Raspberry Bush, in Fork of a Maple.

454. Seed-Carrying purposely done by Animals. — In the cases referred to in the preceding sections, animals have been seen to act as unconscious or even unwilling seed-carriers. Sometimes, however, they carry off seeds with the plan of storing them for food. Ants drag away with them to

their nests certain seeds which have fleshy growths on their outer surfaces. Afterwards they eat these fleshy

FIG. 275. — Red Cedar Trees planted by Birds roosting on Fences.

parts at their leisure, leaving the seed perfectly fit to grow, as it often does.[1]

Squirrels and bluejays are known to carry nuts and acorns about and bury them for future use. These

FIG. 276. — Seed of Bloodroot with Caruncle or Crest, which serves as a Handle for Ants to hold on to. Ant ready to take the seed.

deposits are often forgotten and so get a chance to grow, and in this way a good deal of tree-planting is done.

[1] See Beal's *Seed Dispersal*, pp. 69, 70.

CHAPTER XXX

THE STRUGGLE FOR EXISTENCE AND THE SURVIVAL OF THE FITTEST [1]

455. Weeds. — Any flowering plant which is troublesome to the farmer or gardener is commonly known as a weed. Though such plants are so annoying from their tendency to crowd out others useful to man, they are of extreme interest to the botanist on account of this very hardiness. The principal characteristics of the most successful weeds are their ability to live in a variety of soils and exposures, their rapid growth, resistance to frost, drought, and dust, their unfitness for the food of most of the larger animals, in many cases their capacity to accomplish self-pollination, in default of cross-pollination, and their ability to produce many seeds and to secure their wide dispersal. Not every weed combines all of these characteristics. For instance, the velvet-leaf or butterprint,[2] common in cornfields, is very easily destroyed by frost; the pigweed and purslane are greedily eaten by pigs, and the ragweed by some horses. The horse-radish does not usually produce any seeds.

It is a curious fact that many plants which have finally proved to be noxious weeds have been purposely introduced into the country. The fuller's teasel, melilot, horse-radish, wild carrot, wild parsnip, tansy, oxeye daisy,

[1] See Darwin's *Origin of Species*, Chapters III and IV.

[2] *Abutilon Theophrasti.*

and field-garlic are only a few of the many examples of very troublesome weeds which were at first planted for use or for ornament.

456. Study of Weeds. — Select two or more out of the following list of weeds and report on the qualities which make them troublesome from the farmer's point of view (successful from their own).[1]

LIST OF WEEDS[2]

1. Barn-grass,* *Echinochloa Crusgalli.*
2. Beggar's lice,* *Cynoglossum officinale.*
3. Beggar's-ticks, *Bidens frondosa.*
4. Black mustard,* *Brassica nigra.*
5. Blue thistle,* *Echium vulgare.*
6. Buffalo bur, *Solanum rostratum.*
7. Burdock,* *Arctium Lappa.*
8. Buttercup,* *Ranunculus bulbosus.*
9. Butterweed,* *Erigeron canadensis.*
10. Carpet weed, *Mollugo verticillata.*
11. Charlock,* *Brassica arvensis.*
12. Chess or cheat,* *Bromus secalinus.*
13. Chickweed, *Stellaria media.*
14. Chicory,* *Cichorium Intybus.*
15. Clover dodder,* *Cuscuta Trifolii.*
16. Cocklebur,* *Xanthium spinosum.*
17. Corn cockle,* *Agrostemma Githago.*

[1] This study will be of little value in city schools, since the plants should be examined as they grow. Specimens of the mature weed and of its fruits and seeds may be preserved by the teacher from one season to another for class use. Whole specimens of small plants, such as purslane, may be put into preservative fluid (see Handbook). Ordinary weeds, such as ragweed, pigweed, etc., may be pressed and kept as roughly prepared herbarium specimens, while such very large plants as jimson weed, dock, etc., may be hung up by the roots and thus dried.

[2] Names marked in the list thus * are those of plants introduced from other countries, mostly from Europe.

18. Cow herb,* *Saponaria Vaccaria.*
19. Daisy, oxeye,* *Chrysanthemum Leucanthemum.*
20. Dandelion,* *Taraxacum officinale.*
21. Dock, *Rumex crispus.*
22. Dog fennel,* *Anthemis Cotula.*
23. Fox-tail grass,* *Setaria glauca.*
24. Horse-nettle, *Solanum carolinense.*
25. Jamestown weed or Jimson weed,* *Datura Stramonium* or *D. Tatula.*
26. Johnson grass, *Sorghum halepense.*
27. Mallow,* *Malva rotundifolia.*
28. Milkweed, *Asclepias syriaca.*
29. Nettle, *Urtica gracilis.*
30. Pigweed,* *Amaranthus retroflexus.*
31. Pigweed,* *Chenopodium album.*
32. Plantain,* *Plantago major, P. Rugelii.*
33. Pokeberry, *Phytolacca decandra.*
34. Purslane, *Portulaca oleracea.*
35. Quick-grass,* Witchgrass, *Agropyron repens.*
36. Ragweed, *Ambrosia artemisiifolia.*
37. Rib grass,* *Plantago lanceolata.*
38. Sand bur, *Cenchrus tribuloides.*
39. Shepherd's purse,* *Capsella Bursa-pastoris.*
40. Smartweed, *Polygonum Hydropiper.*
41. Sorrel,* *Rumex Acetosella.*
42. Spanish needles, *Bidens bipinnata.*
43. Sticktights, *Desmodium canadense.*
44. Thistle,* *Cirsium lanceolatum, C. arvense.*
45. Yarrow, *Achillea Millefolium.*

457. Origin of Weeds.[1] — By far the larger proportion of our weeds are not native to this country. Some have been brought from South America and from Asia, but most of the *introduced* kinds come from Europe. The importation of various kinds of grain and of garden-seeds,

[1] See the article "Pertinacity and Predominance of Weeds," in *Scientific Papers of Asa Gray*, selected by C. S. Sargent, Vol. II, pp. 234–242.

mixed with seeds of European weeds, will account for the presence of many of the latter among us. Others have been brought over in the ballast of vessels. Once landed, European weeds have succeeded in establishing themselves in so many cases, because they were superior in vitality and in their power of reproduction to our native plants. This may not improbably be due to the fact that the European and western Asiatic vegetation, much of it consisting from very early times of plants growing in comparatively treeless plains, has for ages been habituated to flourish in cultivated ground and to contend with the crops which are tilled there.

458. Plant Life maintained under Difficulties. — Plants usually have to encounter many obstacles even to their bare existence. For every plant which succeeds in reaching maturity and producing a crop of spores or of seeds there are hundreds or thousands of failures, as it is easy to show by calculation. The morning-glory (*Ipomœa purpurea*) is only a moderately prolific plant, producing, in an ordinary soil, somewhat more than three thousand seeds.[1] If all these seeds were planted and grew, there would be three thousand plants the second summer, sprung from the single parent plant. Suppose each of these plants to bear as the parent did, and so on. Then there would be :

9,000,000 plants the third year.
27,000,000,000 plants the fourth year.
81,000,000,000,000 plants the fifth year.
243,000,000,000,000,000 plants the sixth year.
729,000,000,000,000,000,000 plants the seventh year.

[1] Rather more than three thousand two hundred by actual count and estimation.

It is not difficult to see that the offspring of a single morning-glory plant would, at this rate, soon actually cover the entire surface of the earth. The fact that morning-glories do not occupy any larger amount of territory than they do must therefore depend upon the fact that the immense majority of their seeds are not allowed to grow into mature plants.

There are many plants which would yield far more surprising results in a calculation similar to that just given than are afforded by the morning-glory. For instance, a foxglove capsule contains on an average nearly 1800 seeds. A small foxglove plant bears from 140 to 200 capsules and a large one from 530 to 700. Therefore a single plant may produce over 1,250,000 seeds. A single orchid plant[1] has been shown to produce over 10,000,000 seeds.

459. Importance of Dispersal of Seeds. — It is clear that any means of securing the wide distribution of seeds is of vital importance in continuing and increasing the numbers of any kind of plant, since in this way destruction by overcrowding and starvation will be lessened.

A few of the means of transportation of seeds have been described in Sects. 445–454, but the cases are so numerous and varied that a special treatise might well be devoted to this subject alone.

460. Destruction of Plants by Unfavorable Climates. — Land-plants, throughout the greater part of the earth's surface, are killed in enormous numbers by excessive heat and drought, by floods, or by frost. After a very dry spring or summer the scantiness of the crops, before the era of railroads which nowadays enable food to be brought

[1] *Maxillaria*, see Darwin's *Fertilization of Orchids*, Chapter IX.

in rapidly from other regions, often produced actual famine. Wild plants are not observed so carefully as cultivated ones are, but almost every one has noticed the patches of grass, apparently dead, in pastures and the withered herbaceous plants everywhere through the fields and woods after a long drought.

Floods destroy the plants over large areas, by drowning them, by sweeping them bodily away, or by covering them with sand and gravel.

Frosts kill many annual plants before they have ripened their seeds, and severe and changeable winters sometimes kill perennial plants.

461. Destruction by Other Plants. — Overcrowding is one of the commonest ways in which plants get rid of their weaker neighbors. If the market-gardener sows his lettuce or his beets too thickly, few perfect plants will be produced, and the same kind of effect is brought about in nature on an immense scale. Sometimes plants are overshadowed and stunted or killed by the growth all about them of others of the same kind; sometimes it is plants of other kinds that crowd less hardy ones out of existence.

Whole tribes of parasitic plants, some comparatively large, like the dodder and the mistletoe, others microscopic, like blights and mildews, prey during their whole lives upon other plants.

462. Adaptations to meet Adverse Conditions. — Since there are so many kinds of difficulties to be met before the seed can grow into a mature plant and produce seed in its turn, and since the earth's surface offers such extreme variations as regards heat, sunlight, rainfall, and quality of soil, it is evident that there is a great opportunity

offered for competition among plants. Of several plants of the same kind, growing side by side, where there is room for but one full-grown one, all may be stunted, or one may develop more rapidly than the others, starve them out, and shade them to death. Of two plants of different kinds the hardier will crowd out the less hardy, as ragweed, pigweed, and purslane do with ordinary garden crops. Weeds like these are rapid growers, stand drought or shade well, will bear to be trampled on, and, in general, show remarkable toughness of organization.

Plants which can live under conditions that would be fatal to most others will find much less competition than the rank and file of plants are forced to encounter. Lichens, growing on barren rocks, are thus situated, and so are the fresh-water plants, somewhat like pond-scum in their structure, which are found growing in hot springs at temperatures of 140°, or in some cases nearly up to 200°.

463. Examples of Rapid Increase. — Nothing but the opposition which plants encounter from overcrowding or from the attacks of their enemies prevents any hardy kind of plant from covering all suitable portions of a whole continent, to the exclusion of most other vegetable life. New Zealand and the pampas of La Plata and Paraguay, in South America, have, during the present century, furnished wonderful examples of the spread of European species of plants over hundreds of thousands of square miles of territory. The newcomers were more vigorous, or in some way better adapted to get on in the world than the native plants which they encountered, and so managed to crowd multitudes of the latter out of existence.

The "Russian Thistle" (*Salsola Kali*, var. *tenuifolia*) (Fig. 268), which is merely a variety of the saltwort, so common along the Atlantic coast, was first introduced into South Dakota in flaxseed brought from Russia and planted in 1873 or 1874. In twenty years from that time the plant had become one of the most formidable weeds known, throughout an area of about twenty-five thousand square miles.

464. Importance of Adaptiveness in Plants. — It may be inferred from the preceding sections that a premium is set on all changes in structure or habits which may enable plants to resist their living enemies or to live amid partially adverse surroundings of soil or climate. It would take a volume to state, even in a very simple way, the conclusions which naturalists have drawn from this fact of a savage competition going on among living things, and it will be enough to say here that *the existing kinds of plants to a great degree owe their structure and habits to the operation of the struggle for existence*, this term including *the effort to respond to changes in the conditions by which they are surrounded.*

465. Variation and Mutation. — Probably no two plants of any brood grown from the seed of a given parent plant are exactly alike. The slight differences in size, proportions, character of stems, leaves, flowers, or fruit noticeable among the offspring of the same parent are known as *variations.*

Sometimes the differences are most pronounced, as much so as if some seedlings from a red clover plant should develop into the little white clover, or black walnut trees grow from butternuts. Such marked deviations from the

parent type are called *mutations*. Varieties often (though not nearly always) reproduce themselves and mutations generally do so. In order to get a fair idea of the importance of variation and mutation in bringing about sweeping changes in the species of plants, one should remember that the total number of instances of variations of every kind in a year must be inconceivably large and that the process has gone on for hundreds of thousands of years. Not one in a million of the varieties which appear among wild plants is ever noticed, and among cultivated ones few of the actual cases are observed and recorded.

466. Survival of the Fittest. — Sometimes a new variety or a new species may not be any better suited than the parent form was to hold its own under difficulties. But often the newcomer is found to be hardier, its fruits better adapted for dispersal of the seeds by wind, water, or animals, or some other characteristic may give it an advantage over its competitors. The result of such an advantage is to bring about what is sometimes called *survival of the fittest* and sometimes *natural selection*. Whichever term is used, the meaning is that the kinds of plants which we know to-day have arisen from one or a few primitive ancestors by the action of a great weeding-out process, acting for ages on plants to perpetuate advantageous new forms as they arose.

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KEY AND FLORA

NORTHERN AND CENTRAL STATES

BY

JOSEPH Y. BERGEN, A.M.

REVISED AND ENLARGED

GINN & COMPANY

BOSTON · NEW YORK · CHICAGO · LONDON

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89.12

The Athenæum Press
GINN & COMPANY · PROPRIETORS · BOSTON · U.S.A.

PREFACE

This flora is a considerably enlarged revision of the one prepared by the author in 1901. It does not profess to describe all the conspicuous seed plants of any locality, but rather to comprise a large number of the most available spring-blooming species over an extensive region. More than a hundred species have been added to the list included in the older edition, mainly of plants which range westward to the moderately high plains. The little book may therefore afford a good deal of practice in the determination of species to secondary-school pupils in states even as far west as the Dakotas, Nebraska, Kansas, and Oklahoma. It extends south about to the southern boundary, of Kansas on the west and to that of Virginia on the east.

In the matter of nomenclature it seems best for those who do not wish to be hopelessly sectional to follow the rulings of the Vienna Congress. The author deems himself fortunate to have been able in this connection to avail himself of the decisions of the staff of the Gray Herbarium, as embodied in the seventh edition of Gray's *Manual of Botany*, and to get advice from the same source in regard to names of cultivated plants not described in the Manual. His most sincere thanks are hereby tendered for this invaluable assistance.

At the risk of sometimes seeming pedantic the writer has adopted the practice of discarding, for the most part, such unscientific expressions as "stemless plants," "radical leaves," "calyx adnate to the ovary," and several others. It is certain that if the plant descriptions which contain such terms were now being framed for the first time on the basis of present-day morphology, these terms would not be used.

Most of the plants here described bloom before the end of the school year, and it is believed that all of those which occur toward the southern limits of the territory covered will be found to flower there considerably before the end of June. It

may be found worth while, in the case of some *Umbelliferæ*, *Boraginaceæ*, and *Compositæ*, to collect fruit during the summer before it is to be used, preserve it either dry or in preservative fluid, as may seem best, and use it with freshly collected flowers in the determination of species.

No systematic work with seed plants can be of much use unless the teacher takes constant pains to bring out the idea of actual relationship by descent among the forms studied, and to show, in the simpler cases available, some of the steps of evolution. The beginner must not be allowed to suppose that the flora which he is using contains more than a small fraction of the total number of plants even in the families treated. He must be made to realize that the *Rubiaceæ*, for instance, of which he has fourteen species described, really number as many as 4500 species, and the *Compositæ*, instead of mustering a few dozen strong, number in all at least 12,000 species. For such comparisons Engler's *Syllabus der Pflanzenfamilien* will be found to contain the most recent and compact summary.

A somewhat complete (phanerogamic) flora of the student's region should be constantly in use. For this purpose the author prefers to all others the seventh edition of Gray's *Manual of Botany*. For the convenience of those who may find it necessary to use Britton's *Manual of the Flora of the Northern States and Canada*, the generic name used by Britton will generally be found in parenthesis after the name sanctioned by the Vienna code. In cases where Britton's genus covers only part of the genus as given in this book, a statement to that effect is made, as on p. 186, — B. Fl. species 4 (*Naumburgia*). For suggestions about literature see Bergen and Davis, *Laboratory and Field Manual of Botany*, p. 230.

The novice should find a good deal of help in understanding the structure of some of the more difficult flowers and fruits in the illustrations which accompany several families. Most of these have been redrawn for the present edition by Mr. E. N. Fischer of Boston.

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Cambridge, Massachusetts

HOW TO USE THE KEY AND FLORA

In order to determine an unknown species, the student is first to make a careful examination of the plant in hand. After noting in a general way the appearance of the root, stem, and leaf, including a cross section of the stem, he should study the number of the parts of the flower, then make and draw a cross section and a lengthwise section of it. The kind of symmetry of the calyx and corolla, peculiarities in the shape, structure, or operation of the essential organs, such, for instance, as anthers discharging through chinks in the end, should be noted.

Next, the inquirer should look carefully through the key to the families. He is first to decide whether the plant in question is a Gymnosperm or an Angiosperm; if not a coniferous tree or shrub, it will of course belong to the latter division. He is then to settle the question whether it is a Monocotyledon or a Dicotyledon; then under what division of the group the plant comes; and, finally, to decide upon its family.

Turning now to the page at which the family is described, a rapid inspection of the characteristics of the genera will make it evident to which one the species under examination belongs. It may not infrequently prove that none of the genera described agree with the plant studied, and in that case the student must either consult a larger flora or rest satisfied with having determined the family to which his specimen belongs. The identification of the species, after

the genus has been reached, presents no difficulty in a little flora like the present one.

A single example may suffice to illustrate more in detail the manner of determining species. Suppose the student to have in hand a flowering specimen of lily of the valley. Turning to the key, page 5, it is evident from the statements concerning Gymnosperms that the plant does not belong under that head. Under Angiosperms it is clear, from the numerical plan of the flower (in threes) and the parallel-veined leaves, that the plant is a Monocotyledon. Among Monocotyledons three general groups are designated by as many numbers in parenthesis. The flower in hand belongs under (3) "Flowers not on a spadix." Under this head the choice is first between (*a*) "Carpels numerous and separate" and (*b*) "Carpels united." In the lily of the valley they are united. The next choice is between "* Perianth hypogynous" and "** Perianth not hypogynous." This flower is hypogynous. The families with hypogynous perianth are grouped under three divisions (distinguished by †, ††, ††† respectively), and of these the last, with its "Perianth actinomorphic, its divisions all alike or nearly so, petal-like," corresponds to the flower under examination and refers the student to "10. Lily Family, page 6." Turning to the key to the genera of the Lily family, page 31, two subfamilies are found. Since the plant is not a climber it belongs to "Subfamily I. Liliaceæ Proper."

This subfamily is divided into five groups designated by capital letters. The lily of the valley has an undivided style and springs from a rootstock, therefore it belongs to group B. Reading the descriptions under B, none is found to agree with the plant in hand until the next to the last is reached: "Leaves only 2, directly from the rootstock. Flowers in a raceme, bell-shaped, white, sweet-scented, *Convallaria*."

Referring now to the genus, it is found that there is only one species and that one agrees with the specimen in hand. It is therefore *Convallaria majalis*, and the name (as indicated by the L. which follows it) was given by the great Swedish naturalist, Linnæus.[1]

The author does not believe in spending much of the school time of a class upon identifying species, but would rather recommend comparative studies of as many plants of a group as are accessible, and making these studies thorough enough to bring out fully the idea of the family, the genus, and the species.[2] The descriptions in this flora may be used as a check on the cruder ones which the pupil is first to frame for himself.

[1] It will greatly simplify matters if the teacher throughout selects for examination only such species as are described in the flora.

[2] The teacher will find abundant suggestions for such a course in Spalding's *Introduction to Botany*, pp. 152–260.

KEY TO THE FAMILIES OF FLOWERING PLANTS DESCRIBED IN THIS FLORA

CLASS I

GYMNOSPERMS. Ovules not inclosed in an ovary.

Trees or shrubs. Leaves usually evergreen and needle-shaped, awl-shaped, or scale-like. Flowers monœcious or diœcious. Fruit a scaly cone, or sometimes appearing berry-like. 1. Pine Family, page 13

CLASS II

ANGIOSPERMS. Ovules inclosed in an ovary.

SUBCLASS I. — MONOCOTYLEDONS. Flowers usually with their parts in threes, never in fives. Leaves usually parallel-veined. Cotyledon 1.

	Family	Page
(1) Flowers inclosed by chaffy bracts.		
Flowers 2-bracted. Leaves 2-ranked. Stem cylindrical	4. Grass	22
Flowers 1-bracted. Leaves 3-ranked. Stem triangular	5. Sedge	23
(2) Flowers on a spadix.		
Spadix slender, hairy, and bristly	2. Cat-Tail	20
Spadix fleshy	6. Arum	24
(3) Flowers not on a spadix.		
(*a*) Carpels usually numerous and nearly or entirely separate	3. Water Plantain	21
(*b*) Carpels united.		
* Perianth hypogynous or nearly so.		
† Perianth actinomorphic, its parts similar, green, or chaffy	9. Rush	30
†† Perianth of 2 sets, one sepal-like, the other petal-like.		
Style and stigma 1. Petals 3 or 2, soon disappearing	7. Spiderwort	26

	Family	Page
Styles or stigmas 3, separate. Petals 3, lasting several days. Leaves netted-veined . . .	10. (*Trillium*) Lily	30
Style 1, stigma 3-lobed or 6-toothed. Corolla not actinomorphic. Aquatic herbs with parallel-veined leaves	8. Pickerel Weed	28
††† Perianth actinomorphic, its divisions all alike or nearly so, petal-like	10. Lily	30
** Perianth not hypogynous.		
Anthers 6	11. Amaryllis . .	43
Anthers 3	12. Iris	45
Anthers 1 or 2	13. Orchis . . .	47

SUBCLASS II. — DICOTYLEDONS. Flowers usually with their parts in fives or fours. Leaves netted-veined. Cotyledons 2.

I. Apetalous Division. Flowers without a corolla or without either calyx or corolla.[1]

A

Flowers monœcious or dicœcious, one or both sorts in catkins.		
(1) Staminate flowers in catkins, the pistillate ones solitary or clustered.		
Leaves pinnately compound	16. Walnut . . .	52
Leaves simple	18. Beech	58
(2) Both kinds of flowers in catkins.		
(*a*) Leaves alternate.		
Ovaries in fruit becoming fleshy and combining into an aggregate fruit . . .	20. Mulberry . .	64
Fruit 1-seeded, a drupe or minute nut. Aromatic shrubs	15. Bayberry . .	51
Fruit a capsule, seeds with silky hairs . .	14. Willow . . .	48
Fruit a minute nut or akene. Mostly large shrubs or trees, not very aromatic . .	17. Birch	54
(*b*) Leaves opposite, small parasitic shrubs . .	23. Mistletoe . . .	68

B

Flowers not in catkins, both calyx and corolla wanting	45. Sycamore . .	113

[1] When only one floral envelope is present, this is said to be the calyx and the corolla is considered to be missing.

C

Flowers not in catkins; calyx present, sometimes petal-like.

	Family	Page
(1) Trees or shrubs.		
Flowers not hypogynous; plants not climbing	74. Dogwood	175
Flowers not hypogynous; climbing plants	24. Dutchman's Pipe	68
Flowers hypogynous.		
Style single, not cleft, fruit a key (*Fraxinus*)	79. Olive	189
Style single, not cleft, fruit a drupe	38. Laurel	95
Styles 2 or 2-cleft, fruit 1-celled	19. Elm	62
Styles 2 or 2-cleft, fruit 2-celled	59. Maple	151
Styles 3, each 2-cleft. Ovary 3-celled	54. Spurge	145
(2) Herbs.		
Flowers not hypogynous; ovary 6-celled	24. Dutchman's Pipe	68
Flowers not hypogynous; ovary 1-celled; flowers in umbel-like clusters	22. Sandalwood	67
Flowers hypogynous.		
(*a*) Ovary 1-celled.		
Stamens many	33. Buttercup	83
Stamens few.		
Stipules sheathing the joints	25. Buckwheat	69
Stipules wanting.		
Rather fleshy herbs	26. Goosefoot	72
Not fleshy.		
Ovules on a free central placenta; delicate, soft-leaved herbs. (*Stellaria*)	31. Pink	77
Ovule single, coarse herbs	27. Amaranth	74
(*b*) Ovary several-celled.		
Small prostrate herb; leaves spatulate, whorled	29. Ice Plant	76
Stipules present, not sheathing.		
Style single	21. Nettle	66
Styles 2	20. Mulberry	64
Flowers hypogynous, ovary 3-celled	54. Spurge	145
Flowers hypogynous, ovary 5-10-celled; fruit a berry	28. Pokeweed	75

II. Choripetalous Division. Calyx and corolla both present, the petals not united.

A

Stamens more than 10.

	Family	Page
(1) Trees, shrubs, or woody vines.		
(*a*) Leaves alternate.		
* Ovary 1, simple.		
Fruit a drupe	46. Rose	113
** Ovary 1, compound; fruit dry.		
Ovary 5-celled, 1–2-seeded at maturity	64. Linden	157
Ovary 3-celled, many-seeded	69. Begonia	164
*** Ovary 1, compound; fruit fleshy	46. Rose	113
**** Ovaries numerous.		
† Leaves with stipules.		
Stamens inserted on the receptacle	35. Magnolia	92
Stamens many, monadelphous	65. Mallow	158
Stamens inserted on the calyx	46. Rose	113
†† Leaves not with stipules.		
Small trees	37. Papaw	94
(*b*) Leaves opposite; fruit dry.		
Ovary single, 3–5-celled	44. Saxifrage	109
Ovaries several, inclosed by the calyx tube	36. Calycanthus	94
(2) Herbs.		
(*a*) Ovary single, simple; fruit a berry	34. Barberry	91
(*b*) Ovaries several, simple.		
Stamens inserted on the receptacle	33. Buttercup	83
Stamens inserted on the calyx	46. Rose	113
(*c*) Ovary compound.		
Aquatic herbs, leaves flat	32. Water Lily	82
Marsh herbs, leaves tubular	43. Pitcher Plant	108
Terrestrial herbs.		
* Ovary 1-celled.		
Placentæ central, juice watery	30. Purslane	76
Placentæ parietal, juice milky or colored	39. Poppy	96
Placentæ 2, parietal	41. Caper	107
Placentæ 3 or more, parietal.		
Leaves alternate	42. Mignonette	108
Leaves opposite	66. St. John's-wort	160
Leaves apparently wanting; stems fleshy	70. Cactus	166
** Ovary several-celled; stamens monadelphous	65. Mallow	158
*** Ovary 3-celled; stamens not much if at all monadelphous; stems fleshy, juice acid	69. Begonia	164

B

Stamens not more than 10.

	Family	Page
(1) Trees, shrubs, or woody vines.		
(*a*) Fruit a drupe.		
Stamens 2, rarely 3–4	79. Olive	189
Stamens as many as the petals.		
Flowers bisexual.		
Stamens 4, alternate with the petals	74. Dogwood	175
Stamens 5, alternate with the petals	55. Sumac	148
Stamens 4–5, opposite the petals	62. Buckthorn	154
(*b*) Fruit a berry.		
Stamens alternate with the petals.		
Inserted on the calyx, leaves simple	44. Saxifrage	109
Inserted on a disk surrounding the ovary; leaves compound	72. Ginseng	169
Stamens opposite the petals	63. Grape or Vine	155
(*c*) Fruit a 2-seeded capsule or a key.		
Leaves compound	52. Rue	144
(*d*) Fruit a 2-celled, many-seeded capsule; flowers large, yellow	79. Olive	189
(*e*) Fruit a 3–5-celled capsule; flowers small, greenish, or brown-purple; leaves simple	57. Wahoo	150
(*f*) Fruit 5-lobed, the 5 carpels separating when ripe; flowers rather large, white, or of showy colors; leaves simple	48. Geranium	140
(*g*) Fruit a 1–3-celled capsule, leaves compound, flowers zygomorphic	60. Buckeye	152
(*h*) Fruit a 3-celled bladdery capsule, leaves compound, flowers actinomorphic	58. Bladder Nut	151
(*i*) Fruit a legume	47. Pea or Pulse	126
(2) Herbs.		
(*a*) Ovary single, 1-celled, simple or compound.		
* Corolla actinomorphic or nearly so.		
Sepals and petals 4–5; stamens 5, 10, or 12, distinct.		
Leaves alternate.		
Stigma single	47. Pea or Pulse	126
Stigmas 4 or 2	44. Saxifrage	109
Leaves opposite, punctate, flowers yellow	66. St. John's-wort	160
Leaves opposite, flowers white or red	31. Pink	77
Sepals and petals 4–5; stamens 5, united	68. Passion Flower	163
Sepals 2, petals 4–5	30. Purslane	76

	Family	Page
Sepals 6, stamens hypogynous, opposite the petals	34. Barberry	91
** Corolla zygomorphic.		
Fruit a legume	47. Pea or Pulse	126
Fruit a capsule.		
Stamens 5	67. Violet	161
Stamens 6, in 2 sets	39. Poppy	96
(*b*) Ovary single, 2-5-celled, fruit usually dry.		
* Ovary 2-celled (or 2 carpels nearly separate).		
Flowers in umbels, stamens 5	73. Parsley	170
Flowers not in umbels, petals 4 or 0, stamens 6	40. Mustard	99
Flowers not in umbels, petals 5, stamens 10	44. Saxifrage	109
Flowers not in umbels, petals 3, stamens 6 or 8	53. Polygala	145
** Ovary a 4-celled capsule	71. Evening Primrose	168
*** Ovary of 3 nearly distinct lobes, which become thick and fleshy in fruit	50. Indian Cress	142
**** Ovary a 5-celled capsule.		
† Leaves simple.		
Parasitic white or yellowish herbs, or evergreen herbs, not parasitic, capsule many-seeded	75. Pyrola	177
Terrestrial, not much if at all fleshy, capsule 5-10-seeded	48. Geranium	140
Terrestrial, stem fleshy and translucent, capsule elastic, several-seeded	61. Balsam	153
†† Leaves of 3 leaflets	49. Wood Sorrel	142
(*c*) Ovary of 5 principal cells, each more or less divided by a partition into 2 cells; seeds flattish, with a mucilaginous coating	51. Flax	143
(*d*) Ovary single, 2-5-celled; fruit a berry	72. Ginseng	169
(*e*) Ovaries 2, seeds hairy-tufted	82. Milkweed	194

III. Sympetalous Division. Calyx and corolla both present, the petals appearing more or less united.

(1) Trees, shrubs, or woody vines.

(*a*) Leaves alternate.

* Fruit splitting open.		
Fruit a legume	47. Pea or Pulse	146
Fruit a 5-celled capsule	76. Heath	179
** Fruit not splitting open, a drupe	56. Holly	149
*** Fruit a berry.		

	Family	Page
Ovary superior; seeds few, large	78. Ebony	188
Ovary superior; seeds many, small	89. Nightshade	214
Ovary inferior	76. Heath	179
(*b*) Leaves opposite.		
* Fruit a 2-celled, 2-seeded capsule	95. Madder	227
** Fruit a 2-celled, many-seeded capsule.		
Seeds large, winged	91. Bignonia	222
Seeds not winged except in *Diervilla;* shrubs	96. Honeysuckle	230
*** Fruit a 5-celled capsule	76. Heath	179
**** Fruit a drupe or berry.		
Fruit 1–2-seeded (in *Forsythia* many-seeded); stamens 2	79. Olive	189
Fruit 1–4-seeded; stamens 4	87. Verbena	207
Fruit 1–5-seeded; stamens 5	96. Honeysuckle	230
(2) Herbs.		
(*a*) Ovary superior, flowers regular.		
* Ovary separating into 2 distinct follicles.		
Style single, stamens distinct	81. Dogbane	192
Styles 2, stamens united.	82. Milkweed	194
** Ovary 1-celled.		
Fruit a legume	47. Pea or Pulse	126
Fruit a capsule.		
Leaves alternate.		
Stamens opposite the lobes of the corolla	77. Primrose	184
Stamens alternate with the lobes of the corolla	85. Waterleaf	201
Leaves opposite	80. Gentian	191
Leaves all reduced to mere scales, plants never green, root parasites	92. Broom Rape	223
**** Ovary 2-several-celled.		
Stamens 2 or 4	94. Plantain	225
Stamens 5, cells of the ovary 1–2-seeded.		
Fruit separating into 4 nutlets	86. Borage	203
Fruit a capsule	83. Morning-Glory	197
Stamens 5, cells of the ovary several-seeded.		
Stigma 1	89. Nightshade	214
Stigmas 3	84. Phlox	199
(*b*) Ovary superior, flowers zygomorphic.		
* Ovary 1-celled.		
Fruit a legume	47. Pea or Pulse	126

	Family	Page
** Ovary 2-4-celled.		
† Cells each 1-seeded.		
Ovary deeply 4-lobed	88. Mint	209
Ovary not deeply lobed.		
Stamens 2 or 4	87. Verbena	207
Stamens 8	53. Polygala	145
†† Cells each 2-several-seeded.		
Corolla lobes imbricate in the bud	90. Figwort	217
Corolla lobes convolute in the bud	93. Acanthus	224
(*c*) Ovary inferior.		
Flowers in an involucrate head	100. Composite	239
Flowers not in heads.		
Stamens 3.		
Leaves opposite	97. Valerian	235
Leaves alternate	98. Gourd	236
Stamens 4–5.		
Leaves alternate	99. Campanula	237
Leaves opposite or whorled	95. Madder	227

CLASS I. GYMNOSPERMS

Plants destitute of a closed ovary, style, or stigma. Ovules generally borne naked on a carpellary scale, which forms part of a cone. Cotyledons often several (Fig. 1).

1. PINACEÆ. Pine Family

Trees or shrubs with wood destitute of ducts, with resinous and aromatic juice. Leaves generally evergreen, and needle-shaped or awl-shaped. Flowers destitute of floral envelopes, monœcious or diœcious, the staminate ones consisting of catkin-like spikes of stamens and the pistillate ones consisting of ovule-bearing scales, arranged in spikes, which ripen into cones.

A

Each scale of the cone borne in the axil of a bract. Seeds 2, with wings.

Leaves evergreen, in bundles of 2–5. Pinus, I

Leaves evergreen, solitary, sessile, keeled on both surfaces. Picea, II

Leaves evergreen, solitary, petioled, flat. Tsuga, III

Leaves solitary, evergreen, flat above, keeled below. Abies, IV

Leaves clustered, deciduous, flat. Larix, V

B

Scales of the cone without bracts, cone becoming globular and woody. Leaves linear.

Leaves alternate, deciduous. Taxodium, VI

C

Scales of the cone few, without bracts. Leaves evergreen, generally scale-like or awl-shaped.

Cones dry and thin-scaled.	Thuja, VII
Cones berry-like.	Juniperus, VIII

I. PINUS L.

Sterile flowers somewhat resembling inconspicuous catkins, borne at the base of the young shoot of the season, each flower consisting of pollen-scales in spiral groups (Fig. 1, *2*). Fertile flower spikes consisting of spirally arranged carpel scales, each scale springing from the axil of a bract and bearing at its own base two ovules (Fig. 1, *3*). Fruit a cone, formed of the thickened carpellary scales, ripening the second autumn after the flower opens. Primary leaves, thin and chaffy bud scales, from the axils of which spring the bundles of 2–5 nearly persistent, needle-like, evergreen leaves, 1–15 in. long (Fig. 1).

1. P. Strobus L. White Pine. A tall tree, 75–160 ft. high, much branched and spreading when growing in open ground, but often with few or no living branches below the height of 100 ft. when growing in dense forests. Leaves clustered in fives, slender, 3–4 in. long, smooth and pale or with a whitish bloom. Cones 5–6 in. long, not stout. The wood is soft, durable, does not readily warp, and is therefore very valuable for lumber. In light soil, commonest N.

2. P. Tæda L. Loblolly Pine, Oldfield Pine. A large tree; bark very thick and deeply furrowed, becoming flaky with age; twigs scaly. Leaves in threes, 6–10 in. long, slender, very flexible; sheaths $\frac{2}{3}$–1 in. long. Cones solitary, oblong-conical, 3–5 in. long; scales thickened at the apex, the transverse ridge very prominent and armed with a short, stout, straight or recurved spine. Common, and often springing up in old fields; trunk containing a large proportion of sapwood; timber of little value for outside work.*[1]

3. P. rigida Mill. Northern Pitch Pine. A stout tree, 30–80 ft. high, with rough, scaly bark. Leaves in threes, 3–5 in. long, stiff and flattened. Cones ovoid-conical, 2–3 in. long, their scales tipped with a short, abruptly curved spine. Wood hard, coarse, and resinous, mainly used for fuel. Poor, sandy soil, especially eastward.

[1] Descriptions followed by an asterisk are taken (more or less simplified) from Professor Tracy's flora in the *Southern States Edition.*

4. P. virginiana Mill. Scrub Pine. A small tree, usually 20–30 ft. high, but sometimes much taller; bark of the trunk rough, nearly black; twigs smooth and with a bloom. Leaves in twos, 1–2 in.

Fig. 1. Scotch pine (*Pinus sylvestris*)

1, a twig showing: *a*, staminate catkins; *b*, pistillate catkins; *c*, a cone; *d*, needles. 2, an anther: *a*, side view; *b*, outer surface. 3, a carpel scale: *a*, inner surface; *b*, outer surface. 4, *a* a cone scale, *b* a seed wing, and *c* a seed. 5, section of a seed, showing the embryo. 1 is natural size; parts 2, 3, and 5 are magnified by the amount indicated by comparison with the vertical line alongside each. (After Wossidlo)

long, rigid, sheaths very short. Staminate catkins dull, yellowish-purple, 1 in. long. Cones solitary, short-peduncled, often reflexed, ellipsoid-conic, about 2 in. long; scales thickened at the apex and

armed with a slender, straight or recurved prickle. On dry, sandy soil; wood light, soft, weak, and of little value.*

5. P. sylvestris L. Scotch Pine (wrongly called Scotch Fir). A medium-sized tree, with the older bark reddish and scaly. Leaves in twos, 1½–2½ in. long. Cones rather small and tapering (Fig 1, *1, c*). Cultivated from Europe.

6. P. resinosa Ait. Red Pine, Norway Pine. A tall, rather slender tree, with bark reddish-brown and moderately smooth. Leaves in twos, slender, and 5–6 in. long. Cones borne at the ends of the branches, smooth, about 2 in. long. A valuable timber tree, which often grows in small, scattered clumps; wood firm, pale red, and not very resinous; used in house and bridge building, and for masts and spars.

7. P. palustris Mill. Long-Leaved Pine. A large tree; bark thin-scaled, wood very resinous, old trees with only a few spreading branches near the top. Leaves in threes, 10–15 in. long. Sheaths 1–1¼ in. long, crowded near the ends of very scaly twigs. Staminate catkins 2–3 in. long, bright purple, conspicuous. Cones terminal, ellipsoid-conical, 6–10 in. long, diameter 2–3 in. before opening, 4–6 in. when fully opened; scales much thickened at the apex and armed with a short recurved spine at the end. The most common tree in the pine barrens; wood hard, strong, and durable, especially valuable for floors and inside work.*

II. PICEA Link

Sterile flowers generally axillary (sometimes terminal), borne on the twigs of the preceding year. Fertile flowers terminal. Fruit a nodding, thin-scaled cone, ripening in the first autumn. Leaves evergreen, needle-shaped, four-angled, scattered or spirally arranged.

1. P. mariana BSP. Black Spruce. A small tree, usually only 20 or 30 ft. high, often less. Leaves strongly 4-angled, bluish-green, and glaucous, ½–¾ in. long. Cones ovoid, pointed, ½–1½ in., usually about 1 in. long, persisting sometimes for 20–30 years. Wood of little value except for paper pulp. The tree is especially abundant northward and is of common occurrence in peat bogs.

2. P. rubra Dietrich. Red Spruce. A large tree, 70–80 or even 100 or more feet high, of strict conical habit. Leaves dark green or yellowish and glossy, ½–⅝ in. long. Cones ovoid-oblong, acute, usually 1½–2 in. long, mostly falling the first year. This is the principal timber spruce of the northeastern United States, and furnishes much rather tough lumber for use in floor joists, scantling, and similar purposes.

3. P. canadensis BSP. White Spruce, Skunk Spruce, Cat Spruce. A tall, rather conical tree, 60–70 ft. high. Leaves pale and with a bloom sometimes ¾ in. long. Cones cylindrical, with rounded ends, about 2 in. long, falling inside of one year. A handsome tree, valuable for timber, ranging far northward.

4. P. Abies Karst. Norway Spruce. A large tree. Leaves dark green, ¾–1 in. long. Cones 5–7 in. long. Cultivated from Europe.

III. TSUGA Carrière

Sterile flowers, clusters of stamens springing from the axils of leaves of the preceding year. Cones terminal, on twigs of the preceding year, drooping, thin-scaled, ripening the first year. Leaves minutely petioled, short, flat, white beneath, 2-ranked.

1. T. canadensis Carrière. Hemlock. A large tree, in age branchless below when growing in dense woods. When young the spray is very graceful and abundant. Leaves short-linear. Cones ¾ in. or less in length. The wood is coarse and splintery, but useful for fences and other rough work. The thick reddish bark is of great value for tanning.

IV. ABIES Hill

Sterile flowers from axils of leaves of the preceding year. Cones erect, on the sides of the branches, with deciduous scales, ripening the first year. Leaves scattered, but on horizontal branches appearing 2-ranked, flat above, silvery, and with a prominent midrib below.

1. A. balsamea Mill. Balsam Fir. A slender tree, 50–60 ft., occasionally 80 ft., high, with dense foliage. Leaves narrowly linear, less than 1 in. long. Cones violet-colored until old, cylindrical, 2–4 in. long. The bark contains many large blisters, filled with the well-know Canada balsam. The wood is brittle and of little value.

V. LARIX Mill.

Flower spikes short, opening in early spring, before the leaves; the fertile ones, while still young, of a beautiful crimson color. Fruit a small cone, with thin scales. Leaves none of them scaly, but all needle-shaped, soft, deciduous, very numerous, in little brush-like bundles.

1. **L. laricina** Koch. American Larch, Tamarack, Hackmatack (wrongly, but quite generally, called Cypress and Juniper). A tall, slender tree, 30–100 ft. high. Leaves slender and less than 1 in. long, very pale bluish-green. Cones $\frac{1}{2}$–$\frac{3}{4}$ in. long, few-scaled. Wood hard, tough, and heavy, of considerable use for shipbuilding.

2. **L. decidua** Mill. European Larch. Leaves bright green and longer. Cones longer than in the preceding species and many-scaled. Cultivated from Europe.

VI. TAXODIUM Richard

Trees. Leaves spreading so as to appear 2-ranked, deciduous. Flowers monœcious, appearing before the leaves; staminate ones numerous, globose, forming long, terminal, drooping, panicled spikes; anthers 2–5-celled. Pistillate flowers single or in pairs, bractless, the peltate scales 2-ovuled. Cone globose; the very thick woody scales angular, separating at maturity. Seeds 3-angled, pyramidal.*

1. **T. distichum** Richard. Bald Cypress. A very large tree; bark dark brown, rough, fibrous; many of the twigs deciduous with the leaves. Leaves alternate, opposite, or whorled, 2-ranked, flat, linear, $\frac{1}{2}$–$\frac{3}{4}$ in. long. Cones terminal, globose, about 1 in. in diameter; ends of the scales much thickened, wrinkled, and with a distinct triangular marking. Common in swamps and on the borders of streams; wood reddish, soft, light; specially valued for shingles and fence posts, and for boat building.*

VII. THUJA L.

Flowers small, terminal, monœcious, on different branches. Stamens each consisting of a scale-like portion bearing 4 anther-like cells. Pistillate flowers consisting of a few overlapping scales which ripen into a small, loose cone. Leaves evergreen, opposite, and closely overlapping on the stem, of two kinds, those on the more rapidly growing twigs awl-shaped, the others mere scales.

1. **T. occidentalis** L. Arbor Vitæ, Cedar. A small tree, 20–50 ft. high, with soft, fibrous bark. Leaves mostly awl-shaped and blunt. Cones ellipsoidal, their scales 2-seeded. Grows on rocky ledges, but reaches its greatest size in cool cedar swamps. Wood soft, yellowish, fragrant, durable, prized for shingles and fence posts.

VIII. JUNIPERUS L.

Flowers very small, lateral, dicecious, or sometimes monœcious. Scales of the staminate flower shield-shaped, with 3–6 anther cells. Fertile flowers with 3–6 fleshy scales which unite into a berry-like, 1–3-seeded fruit. Leaves awl-shaped or scale-shaped.

1. J. communis L. JUNIPER. A low, spreading shrub (one variety prostrate in circular masses). Leaves linear-awl-shaped, with needle-like points, each marked with a distinct stripe of bloom along the center of the upper surface, borne in whorls of three. Fruit a dark blue aromatic berry, $\frac{1}{4}$ in. or more in diameter. Grows in dry pastures and on sterile hillsides N.

2. J. virginiana L. RED CEDAR, SAVIN. Ranges in size and shape from a low, rather erect shrub, to a conical tree 90 ft. high. Leaves of two kinds, those on the rapidly growing shoots awl-shaped and pointed, those on the shortest twigs scale-shaped, obtuse, or nearly so, and closely appressed to the stem. Fruit small, bluish, with a white bloom. Found all the way from British America to Florida. Wood soft, fragrant, reddish, exceedingly durable in the ground, valued for the manufacture of moth-proof chests and especially for lead pencils.

CLASS II. ANGIOSPERMS

Plants with a closed ovary, in which the seeds are matured. Cotyledons 1 or 2.

SUBCLASS I. MONOCOTYLEDONOUS PLANTS

Stems with the fibrovascular bundles scattered among the parenchyma cells; in perennial plants no annual rings of wood. Leaves usually parallel-veined, alternate, nearly always entire. Parts of the flower generally in threes (never in fives). Cotyledon 1.

2. TYPHACEÆ. Cat-Tail Family

Perennial marsh or aquatic plants. Rootstock stout, creeping; stem simple, cylindrical, erect. Leaves simple, strap-shaped, sheathing at the base, nerved and striate. Flowers monœcious, in a single terminal spike, staminate part of the spike uppermost, each part subtended by spathe-like deciduous bracts. Perianth of fine bristles. Staminate flowers sessile, stamens 2–7; filaments connate, subtended by minute bracts. Pistillate flowers short-pediceled. Ovary 1–2-celled; styles 1–2. Fruit small, nut-like.*

TYPHA L.

Characters of the family.

1. **T. latifolia** L. Cat-Tail. Stem erect, jointed below, 5–8 ft. high. Leaves nearly as long as the stem, about 1 in. wide, netted and with a bloom. Spike cylindrical, dark brown or black; staminate portion above the pistillate, usually without any interval between them, each 4–8 in. long and about 1 in. in diameter. Fruit furrowed. Common in marshes and shallow ponds.*

3. ALISMACEÆ. Water Plantain Family

Annual or perennial marsh herbs, usually with creeping runners or rootstocks. Stems scape-like. Leaves long-petioled, sheathing at the base; petiole rounded; blade nerved, netted, or sometimes wanting. Flowers in racemes or panicles, bisexual, monœcious or dicœcious; pedicels in bracted whorls. Sepals 3, persistent; petals 3 or wanting. Stamens 6 or more. Ovaries few or many, 1-celled, 1-seeded; style short or none. Fruit a 1-seeded akene.*

I. SAGITTARIA L.

Perennial; rootstocks mostly knobby or tuber-bearing. Scapes erect or decumbent. Leaves long-petioled, sheathing at the base, the blade round and netted, or wanting. Flowers monœcious or dicœcious, racemed in 3-bracted whorls of threes, the upper flowers usually staminate. Sepals 3, persistent; petals 3, withering-persistent or deciduous. Stamens few or many. Ovaries in globose heads, 1-ovuled; style short, persistent. Fruit a subglobose head of flattened akenes.*

1. S. latifolia Willd. Broad-Leaved Arrowhead. Leaves very variable in size and shape, from broadly sagittate to linear, those growing on the drier soil being usually the broader; petioles 6–30 in. long. Scape smooth or slightly downy, 6–36 in. high; bracts acute. Flowers monœcious or sometimes dicœcious, white, 1 in. or more in width; pedicels of the staminate flowers twice the length of those of the fertile flowers. Filaments long, smooth, and slender. Akenes with beak nearly horizontal. Ditches and muddy places.*

2. S. graminea Michx. Grass-Leaved Sagittaria. Leaves long-petioled, lanceolate, or elliptical, and acute at each end, 3–5-nerved, or often linear, the earlier often reduced to flattened petioles. Scape slender, usually longer than the leaves, simple, weak, often prostrate in fruit; bracts small, ovate, connate at the base. Flowers monœcious or dicœcious, on long, thread-like pedicels, about $\frac{1}{3}$ in. wide. Stamens 10–20, filaments downy. Akenes nearly beakless. In ditches and shallow pools.*

II. ALISMA L.

Annual or perennial herbs. Leaves erect or floating, blades prominently ribbed and netted, or even pinnately veined.

Scapes erect, becoming longer than the leaves, cylindrical, spongy. Flowers bisexual, in paniculate, 3-bracted umbels, small, white or pink. Stamens 6–9. Ovaries numerous in one or more whorls on a flat receptacle. Fruit 1-seeded akenes which are ribbed on the back and sides.*

Fig. 2. Diagrammatic representation of a several-flowered grass spikelet

g, *g'*, the glumes; *p*, *p'*, the palets; *l*, lodicules; *f*, a flower. The axis is much lengthened, to separate the flowers. (After Schimper)

Fig. 3. Spike-like panicle of vernal grass (*Anthoxanthum*)

a, mature anthers. (Slightly enlarged)

1. A. Plantago-aquatica L. Water Plantain. Perennial; root fibrous. Leaves ovate or somewhat cordate, 5–7-nerved when erect, floating leaves narrower and sometimes linear. Scapes usually single; panicle 1–2 ft. long; flowering branches whorled, subtended by three narrow, striate bracts; pedicels slender, elongated. Ovaries 15–20 in a single whorl; base of the short style persistent, forming a beak at the inner angle of the akene. Akenes obliquely obovate, 2–3-keeled on the back. Common in ponds and muddy places.*

4. GRAMINEÆ. Grass Family

Mostly herbs, with usually hollow stems, closed and enlarged at the nodes. Leaves alternate, in two ranks, with sheathing bases, which are split open on the side opposite the blade. Flowers nearly or quite destitute of floral envelopes, solitary, and borne in the axils of scaly bracts, which are arranged in two ranks

overlapping each other on 1–many-flowered *spikelets;* these are variously grouped in spikes, panicles, and so on. Fruit

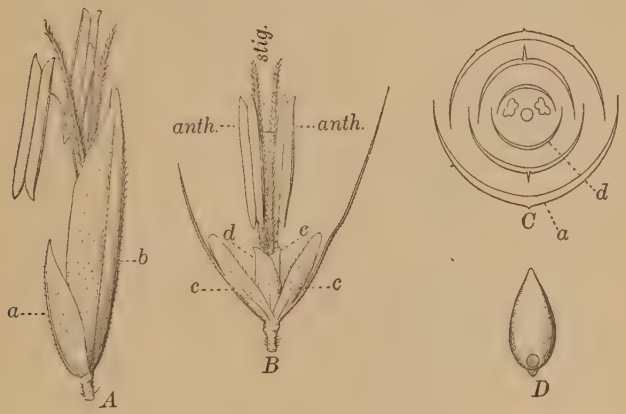


FIG. 4. Vernal grass (*Anthoxanthum*)

A, a one-flowered spikelet: *a*, *b*, the outer empty glumes. *B*, a spikelet with the outer glumes removed: *c*, *c*, the inner empty glumes (neuter flowers) with long, bristle-shaped appendages; *d*, *e*, palets; *anth.*, anthers; *stig.*, stigmas. *C*, diagram of cross section of a spikelet: *a*, glume; *d*, palet. *D*, a fruit. (All magnified.) (After Cosson and De Saint-Pierre)

a grain. (The family is too difficult for the beginner, but the structure and grouping of the flowers may be gathered from a careful study of Figs. 2, 3, 4.)

5. CYPERACEÆ. SEDGE FAMILY

Grass-like or rush-like herbs, with solid, usually triangular, stems, growing in tufts. The sheathing base of the generally 3-ranked leaves, when present, is not slit as in grasses. The flowers are usually somewhat less inclosed by bracts than those of grasses; the perianth is absent or rudimentary; stamens generally 3; style 2-cleft or 3-cleft.

The flower cluster and the flower of a sedge may be understood from an inspection of Fig. 5.

The species are even more difficult to determine than those of grasses.

FIG. 5. Inflorescence, flower, and seed, of a sedge
(Great Bulrush, *Scirpus lacustris*)

A, magnified flower, surrounded by a perianth of hypogynous bristles; *B*, the seed; *C*, section of the seed, showing the small embryo inclosed in the base of the endosperm. (After Lindley)

6. ARACEÆ. ARUM FAMILY

Perennial herbs, with pungent or acrid juice. Leaves often netted-veined. Small, unisexual or bisexual flowers, clustered

along a peculiar fleshy spike called a *spadix*, and frequently more or less covered by a large, hood-like bract called a *spathe*. Perianth, when present, of 4–6 parts; often wanting. Fruit usually a berry.

I. ARISÆMA Martius

Perennial herbs, springing from a corm or a tuberous rootstock. Spathe rolled up at base. Summit of spadix naked, the lower part flower-bearing; staminate flowers above, pistillate ones below. Stigma flat. Ovary 1-celled. Berry 1–few-seeded.

1. A. triphyllum Schott. INDIAN TURNIP, JACK-IN-THE-PULPIT. Leaves generally 2, each of 3 elliptical-ovate, pointed leaflets. Spadix club-shaped, bearing usually only one kind of fully developed flowers; that is, full-sized pistillate and rudimentary staminate ones, or the reverse. Spathe much longer than the spadix, and covering it like a hood. Corm turnip-like, but much wrinkled, very starchy, and filled with intensely burning juice.

2. A. Dracontium Schott. GREEN DRAGON, DRAGON ROOT. Leaf usually single, divided into 7–11 rather narrow, pointed leaflets; spadix tapering to a long, slender point, often bearing fully developed staminate and pistillate flowers.

II. SYMPLOCARPUS Salisb. (SPATHYEMA)

Rootstock very stout, with many long, cylindrical roots. Leaves clustered, very large, and entire. Spathe shell-shaped, very thick. Spadix globular; thickly covered with bisexual flowers. Sepals 4. Stamens 4. Style 4-angled. Fruit globular or ellipsoidal, with the seeds slightly buried in the enlarged spadix.

Coarse, stemless herbs, with a powerful scent like that of the skunk and of onions.

1. S. fœtidus Nutt. SKUNK CABBAGE. Leaves many, slightly petioled, 1–2 ft. long, appearing after the flowers. The latter are usually seen before the ground is wholly free from frost, often earlier than any other flower. Bogs and wet meadows, very common N.

III. ACORUS L.

Rootstocks horizontal, long, and moderately stout, aromatic. Leaves long, upright, sword-shaped. Spathe much like the

leaves. Spadix projecting from the edge of the spathe, consisting of numerous bisexual flowers. Sepals 6. Stamens 6. Ovary 2–3-celled, with numerous ovules. Fruit 1–few-seeded.

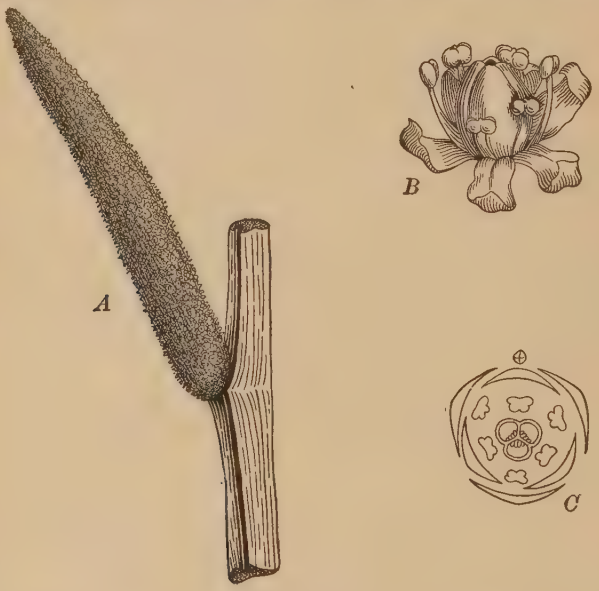


FIG. 6. *Acorus Calamus*

A, spadix; *B*, a single flower, enlarged; *C*, diagram of flower, enlarged. (After Schimper)

1. A. Calamus L. SWEET FLAG. Scape with a long, leaf-like prolongation (spathe) beyond the green, very closely flowered spadix. Along borders of brooks and swamps.

The rootstocks furnish the well-known calamus or "sweet flag root" sold everywhere by druggists.

7. COMMELINACEÆ. SPIDERWORT FAMILY

Herbs, with slimy or mucilaginous juice; stems somewhat succulent, jointed, leafy, simple or branched. Leaves simple, succulent, narrow, entire, sheathing at the base, sheaths entire

or split. Flowers in terminal cymes or umbels, bisexual, often zygomorphic. Sepals 3, persistent, foliaceous or colored. Petals 3, soon falling or liquefying. Stamens 6 or fewer, often some of them abortive. Ovary 2–3-celled; style single; stigma entire or 3-lobed. Fruit a 2–3-celled, 2–3-valved capsule; seeds solitary or several in each cell.*

I. TRADESCANTIA L.

Perennial, stem simple or branched. Leaves very narrow. Flowers in terminal and axillary bracted umbels, actinomorphic, 1 in. broad. Sepals 3, herbaceous. Petals 3, soon falling, or liquefying to jelly. Stamens 6, sometimes 3 shorter than the others; filaments bearded or smooth. Ovary 3-celled, with 2 ovules in each cell; pedicels recurved in fruit. Capsule 3-celled, 3-valved, 3–6-seeded.*

1. T. virginiana L. SPIDERWORT. Stem erect, stout, smooth, or with long, soft hairs, 1–2 ft. high. Leaves linear, keeled, often purple-veined, long, taper-pointed, 1 ft. or more in length. Bracts similar to the leaves. Umbels sessile, 2–many-flowered, flowers in 2 rows in the bud. Petals blue or purple, twice as long as the sepals. Stamens blue, filaments densely bearded. Capsule ovoid or oblong. On dry, sandy soil.*

2. T. pilosa Lehm. HAIRY SPIDERWORT. Stem stout, erect or zigzag, branched, with long, soft hairs, or nearly smooth, 1–2 ft. high. Leaves linear-oblong, taper-pointed at the apex, narrowed at the base, hairy on both sides. Umbels axillary and terminal, many-flowered. Pedicels and sepals with soft, glandular hairs. Flowers blue or purple, $\frac{3}{4}$–1 in. wide. Seeds pitted. In rich soil.*

II. COMMELINA L.

Annual or perennial, stem branching, erect or procumbent, smooth or downy. Leaves petioled or sessile, entire, the floral ones heart-shaped, folded, and forming a spathe inclosing the base of the cymes. Flowers not actinomorphic. Sepals mostly colored, 1 of them smaller. Petals blue, unequal, 2 of them kidney-shaped and long-clawed, the third one smaller. Stamens 6, only 3 of them fertile; filaments smooth. Capsule 1–3-celled; seeds 1–2 in each cell.*

1. C. virginica L. VIRGINIA DAYFLOWER. Stem erect, downy, 1–2 ft. high. Leaves lanceolate to oblong-lanceolate, taper-pointed, 3–5 in. long, somewhat rough above; sheaths inflated, hairy, the opening often fringed. Spathes containing a slimy secretion. Flowers 1 in. wide, the odd petal lanceolate. Capsule 3-seeded, the dorsal cell not splitting open. On moist, sandy soil.*

III. ZEBRINA Schnizl.

Trailing or slightly climbing herbs. Leaves often striped. Flowers usually in pairs. Calyx with a short tube, regularly or irregularly 3-parted. Corolla nearly actinomorphic, with tube longer than the calyx. Filaments naked or bearded. Ovary 3-celled, 3–6-ovuled.

1. Z. pendula Schnizl. WANDERING JEW. Stems perennial, prostrate or nearly so, branching freely, rooting easily at the nodes. Leaves somewhat succulent, lance-ovate or oblong, crimson beneath, green or dark purplish above, often with two wide silvery stripes. Cultivated from Mexico.

8. PONTEDERIACEÆ. PICKEREL-WEED FAMILY

Perennial marsh or aquatic herbs, stems simple or branched, succulent. Leaves simple, alternate. Flowers solitary or spiked, each subtended by a leaf-like spathe, perfect, mostly not actinomorphic. Perianth corolla-like, 6-parted. Stamens 3 or 6, unequal, inserted irregularly in the tube or throat of the perianth. Ovary superior, 1- or 3-celled; style single; stigma entire or toothed. Fruit a 1-seeded utricle.*

PONTEDERIA L.

Stem erect, from a thick, creeping rootstock, bearing a single leaf above the middle and several sheathing, bract-like leaves at its base. Radical leaves numerous, thick, parallel-veined. Petiole long, from a sheathing base. Flowers in terminal spikes. Perianth 2-lipped, lobes of the upper lip ovate, of the lower oblong, spreading. Stamens 6, the 3 upper short and often imperfect, the 3 lower protruding. Ovary 3-celled,

FIG. 7. Rushes

A, plant of *Juncus tenuis*, one half natural size; *B*, flower of same, magnified; *C*, fruit magnified; *D*, flower of wood rush (*Luzula*), magnified. (*D*, after Warming)

but only 1 cell ovule-bearing; the 1-seeded utricle inclosed by the base of the perianth.*

1. P. cordata L. Pickerel Weed. Stem stout, erect, 2–4 ft. high. Leaves long, from heart-shaped to lanceolate and often halberd-shaped; apex and basal lobes obtuse, finely nerved. Spike dense, 2–4 in. long; peduncles inclosed by the spathe. Perianth hairy, blue, the upper lip with 2 yellow spots; tube 6-ribbed, curved, rather longer than the lobes. Ovary oblong. In ponds and slow streams.*

9. JUNCACEÆ. Rush Family

Grass-like perennial or annual herbs, mostly growing on wet soil. Stems mostly erect but sometimes creeping, simple or branched, naked or leafy and jointed. Leaves cylindrical, sheathing at the base, very slender and pointed or flattened and grass-like. Flowers in cymes or panicles, which may be very loose and spreading, or so compact as to form a head, sometimes with a rigid scape prolonged beyond the flower cluster. Flowers usually bracted. Perianth of 6 nearly equal, scale-like, persistent divisions. Stamens 3 or 6, inserted on the base of the perianth. Ovary free, 1- or 3-celled, many-ovuled; style single; stigmas 3, usually hairy. Fruit a 1- or 3-celled, 3–many-seeded capsule. [Most species flower late in the season, and their identification is too difficult for one without considerable experience.]*

10. LILIACEÆ. Lily Family

Mostly herbs. Flowers actinomorphic. Perianth free from the ovary. Stamens nearly always 6, one before each division of the perianth. Ovary usually 3-celled; fruit a pod or berry, few–many-seeded.

Except in the genus Trillium the divisions of the perianth are colored nearly alike.

SUBFAMILY I. LILIACEÆ PROPER

Not tendril climbers, rarely dicœcious.

A

Styles or sessile stigmas 3, more or less separate.

Leaves flat, lanceolate, or spatulate. Flowers dicœcious, showy. Chamælirium, I

Leaves grass-like. Flowers bisexual, showy. Amianthium, II

Leaves 3-ranked, strongly nerved and plaited. Flowers somewhat moncœcious, small. Veratrum, III

B

Style undivided (in No. XXIII, 3 sessile stigmas). Plants from rootstocks.

Leaves perfoliate. Flowers solitary, drooping, yellow. Uvularia, IV

Leaves broad, clasping. Flowers solitary or nearly so, drooping, yellow. Oakesia, V

Leaves scale-like. Thread-like branches borne in their axils. Flowers small, bell-shaped. Asparagus, XVIII

Leaves several–many, sessile or clasping, alternate. Flowers small, 6-parted, white, in a terminal simple or compound raceme. Smilacina, XIX

Leaves only 2–3, sessile or slightly petioled. Flowers very small, 4-parted, solitary or in a small terminal cluster. Maianthemum, XX

Leaves clasping. Flowers solitary or in pairs, greenish-white or rose-purple, borne on pedicels abruptly bent near the middle. Streptopus, XXI

Leaves nearly sessile or partly clasping. Flowers axillary, greenish, on pedicels jointed near the flower. Polygonatum, XXII

Leaves only 2, directly from the rootstock. Flowers in a raceme, bell-shaped, white, sweet-scented. Convallaria, XXIII

Leaves 3, netted-veined. Flower single, large, terminal. Trillium, XXIV

C

Style undivided. Plants from fibrous roots.

Flowers yellow or orange. Hemerocallis, VIII
Flowers white. Yucca, XVII

D

Style usually undivided. Plants from coated or solid-looking bulbs.

Leafy-stemmed plants. Flowers large, solitary, or apparently umbeled. Fritillaria, X

Apparently stemless plants.

(*a*) Plants with the smell of onions or garlic. Flowers umbeled. Allium, VI
(*b*) Plants scentless. Flowers umbeled. Nothoscordum, VII
(*c*) Flower solitary, erect, large. Tulipa, XII
(*d*) Flower solitary, nodding. Erythronium, XI
(*e*) Flowers racemed. Perianth with hardly any tube. Stigma a single knob. Scilla, XIII
(*f*) Flowers racemed. Perianth with hardly any tube. Stigma 3-cleft. Camassia, XIV
(*g*) Flowers corymbed. Perianth with hardly any tube. Leaves linear. Ornithogalum, XV
(*h*) Flowers racemed. Perianth with a tube. Leaves lance-linear. Hyacinthus, XVI

E

Style undivided. Plants from scaly bulbs. Lilium, IX

SUBFAMILY II. SMILACEÆ

Climbers, often tendril-bearing. Flowers diœcious. Smilax, XXV

I. CHAMÆLIRIUM Willd.

Rootstock short and thick, bitter. Stem simple, erect, leafy, smooth. Lower leaves spatulate to obovate, the stem leaves narrower. Flowers small, white, in a spike-like raceme, diœcious. Perianth of 6 linear-spatulate segments. Stamens 6, filaments longer than the perianth. Ovary 3-celled; styles 3. Fruit an ovoid, 3-angled, many-seeded capsule.*

1. C. luteum Gray. UNICORN ROOT, DEVIL'S BIT. Stem furrowed, staminate plants 1–2 ft. high, pistillate taller, often 3 ft. or more. Lower leaves obovate, clustered, the upper small and bract-like. Staminate racemes slender and drooping, the pistillate erect. Flowers short-pediceled. Capsule 3-valved, seeds linear-oblong, winged at the ends. On low ground.*

II. AMIANTHIUM Gray. (CHROSPERMA)

Stem simple, glabrous, erect from a bulbous base. Leaves long and slender. Flowers white, in a simple terminal raceme, bisexual. Perianth of 6 segments which are sessile and glandless. Stamens 6, somewhat perigynous. Ovary 3-lobed, 3-celled; fruit a dehiscent, 3-lobed capsule, the lobes becoming awl-shaped by the persistent style bases; cells few-seeded.*

1. A. muscætoxicum Gray. FLY POISON. Bulb ovoid or oblong. Stem somewhat angled below, 1–3 ft. high. Lower leaves strap-shaped, channeled, the upper small and bract-like. Raceme dense, cylindrical, pedicels from the axils of minute ovate bracts. Perianth segments ovate, white, becoming greenish, nearly as long as the slender stamens. Styles spreading. Capsule with divergent lobes; seeds ovoid, red. In rich woods.*

III. VERATRUM L.

Simple-stemmed perennials. Roots fibrous, from the thickened base of the stem, poisonous, emetic. Leaves 3-ranked, plaited, and veiny. Flowers panicled, greenish or brownish. Sepals 6, spreading, nearly hypogynous. Stamens shorter than the perianth, and somewhat perigynous. Ovary of 3 carpels united at base. Fruit a few-seeded capsule, splitting into 3 parts.

1. V. viride Ait. WHITE HELLEBORE, INDIAN POKE. Stem stout, 2–7 ft. high, very leafy. Flowers very numerous, in a panicle, composed of spike-like racemes. Sepals yellowish-green. Wet meadows and brooksides.

2. V. Woodii Robbins. Stem slender, 2–5 ft. high, not very leafy. Flowers in a long, narrow panicle. Sepals greenish-purple or almost black. Woods and dry hillsides.

IV. UVULARIA L.

Rather low plants with short rootstocks. Leaves alternate, broad, and parallel-veined. Flowers yellow or yellowish,

drooping, borne singly at the end of the forking stem. Perianth of 6 similar and separate narrow spatulate sepals, each grooved and nectar-bearing inside toward the base. Stamens 6, with linear anthers, which are much longer than the filaments. Style 3-cleft. Pod 3-lobed, 3-celled, few-seeded.

1. U. perfoliata L. Mealy Bellwort. Leaves much as in the preceding species. Flowers very pale yellow, with shining grains on the inner surfaces of the twisted sepals; anthers sharp-pointed. Plant about two-thirds the size of the preceding.

2. U. grandiflora Sm. Larger Bellwort. Leaves oblong, with the base clasping the stem so as to make it appear to run through the leaf a little way from the base. Flowers greenish-yellow, 1½ in. long; anthers obtuse. A leafy plant, 1–2 ft. high.

V. OAKESIA Wats.

Plants with much the aspect of the preceding genus, but with merely sessile leaves, triangular winged pods, and slender, creeping rootstocks.

1. O. sessilifolia Wats. Wild Oats, Straw Lilies. Stem slender, zigzag. Leaves lance-oval, thin, smooth, pale beneath, 1–1½ in. long. Flower cream color, nearly 1 in. long.

VI. ALLIUM L.

Herbs appearing stemless from coated bulbs with the characteristic odor of onions. Bulbs solitary or clustered. Leaves narrowly linear or slender-tubular, with a bloom. Flowers small, on slender pedicels, in terminal umbels on naked scapes, the umbels often bracted or inclosed in a spathe. Perianth 6-parted, persistent; stamens 6, somewhat perigynous, filaments filiform or dilated below. Ovary sessile, 3-celled; style thread-like, jointed; stigma entire. Fruit a 3-celled, 3-valved, few-seeded capsule. Flowers sometimes changed into bulblets.*

1. A. reticulatum Don. Resembling *A. Nuttallii*, but with larger bulbs. Leaves narrowly linear. Scape slender; bracts usually 2, taper-pointed; pedicels slender, ¼–½ in. long. Flowers white or pink; segments of the perianth thin. Capsule crested. W.

2. A. Nuttallii Wats. Bulbs ovoid, their coats with a fibrous network. Leaves basal, narrowly linear. Scape 4–8 in. high; bracts

3 or 2; pedicels $\frac{1}{3}$–$\frac{1}{2}$ in. long. Flowers rose color or white, the segments of the perianth becoming rigid in the fruit. On prairies W. and S.W.

3. A. canadense L. Meadow Garlic. Bulbs ovoid, the outer coats of white and thin, dry, netted fibers. Leaves narrowly linear, flat, or concave above. Scape cylindrical, 1 ft. high. Bracts of the umbel 2–3, ovate, acuminate; umbel consisting mostly of sessile bulblets. The few flowers long-pediceled, rose-colored. Perianth about as long as the stamens. Filaments dilated below. Capsule shorter than the perianth, 6-toothed, ovules 2 in each cell. On moist soil.*

4. A. mutabile Michx. Wild Onion. Bulbs ovoid, their coats with a very prominent, fibrous network. Leaves basal, channeled, narrowly linear. Scape 1–2 ft. high, bracts taper-pointed, pedicels almost 1 in. long. Umbel rarely bearing bulblets. Flowers pink, rose color, or white; segments of the perianth thin. In moist soil S. and W.

5. A. vineale L. Field Garlic. Bulb mostly solitary. Leaves cylindrical, hollow, very slender. Scape slender, sheathed below the middle by the bases of the leaves. Umbels often crowded with bulblets. A troublesome weed in moist meadows and fields eastward, giving milk a strong flavor of onions or garlic. Naturalized from Europe.

VII. NOTHOSCORDUM Kunth

Scape-bearing herbs resembling *Allium*, but with no odor of onions. Flowers yellow or yellowish-green, in a loose, erect umbel, with 2 bracts.

1. N. bivalve Britton. Bulb small, often with little bulbs at its base. Leaves narrowly linear. Scape not exceeding 1 ft. high, the umbel 2-bracted, pedicels thread-like, at length 1–2 in. long. Flowers $\frac{1}{2}$ in. long or less, the perianth segments narrowly oblong, thin. On prairies and in open woods.

VIII. HEMEROCALLIS L.

Perennial, from a fascicle of fleshy roots. Stem erect, branched, smooth. Leaves mostly basal and linear. Flowers on branching scapes, large, yellow or orange, solitary or corymbed. Perianth funnelform, with a spreading limb much longer than the tube. Stamens 6, inserted in the top of the tube, shorter than the lobes, curved upward. Ovary 3-celled, many-ovuled; style longer than the stamens, curved upward; stigma knobbed. Fruit a 3-celled, 3-angled capsule.*

1. H. fulva L. DAY LILY. Scapes stout, branched above, with a few bract-like leaves, smooth, 3–5 ft. high. Leaves very long, strap-shaped, acute, channeled. Flowers short-pediceled, tawny-yellow; perianth lobes oblong, netted-veined, lasting only one day. Introduced from Asia and common in old gardens.*

IX. LILIUM L.

Perennial, from scaly bulbs; stem erect, leafy, usually tall and slender. Leaves sessile, scattered or whorled. Flowers large, erect or drooping. Perianth corolla-like, deciduous; segments 6, spreading or recurved above, sessile or clawed, each with a nectar-bearing groove near the base. Stamens 6, elongated; anthers linear, versatile. Ovary 3-celled, many-ovuled; style long and slender; stigma 3-lobed. Fruit a 3-celled, dehiscent, many-seeded capsule.

1. L. longiflorum Thunb. LONG-FLOWERED WHITE LILY. Stem 1–3 ft. high. Leaves thick, lanceolate, scattered. Flower single, pure white, funnel-shaped, 5–6 in. long. Var. **eximium**, the Easter lily, bears several very showy and sweet-scented flowers. Cultivated from China and Japan.

2. L. philadelphicum L. WILD RED LILY. Stem 2–3 ft. high. Leaves linear-lanceolate, the upper ones generally whorled. Flower usually solitary (sometimes 2 or 3), erect, reddish-orange, with tawny or purplish spots inside. Sepals with claws. Dry or sandy ground, borders of thickets, etc.

Var. **andinum** Ker. WESTERN RED LILY. Stem rather slender. Leaves linear, all alternate or the upper ones whorled. Flowers 1–3, erect. Segments of the perianth red, orange, or yellow, spotted beneath, the claw shorter than the blade. In dry soil W.

3. L. canadense L. WILD YELLOW LILY, MEADOW LILY. Stem 2–5 ft. high. Leaves lanceolate, 3-nerved, the margins and nerves roughish with short hairs, whorled. Flowers usually 3, sometimes more numerous, all nodding, on peduncles 3–6 in. long, yellow or orange, with dark purple or brown spots inside. Sepals without claws, recurved. Moist meadows and borders of woods.

X. FRITILLARIA L.

Leafy-stemmed perennials, from scaly or coated bulbs. Flowers single or several, nodding. Perianth bell-shaped, a nectar-bearing spot above the base of each division. Stamens as long as the petals.

1. F. Meleagris L. Guinea-Hen Flower. Stem 1 ft. high. Leaves linear, alternate, channeled. Flower usually single, large, purplish, checkered with blue and purple or yellow. Cultivated from Europe.

2. F. imperialis L. Crown Imperial. Stem 3–4 ft. high. Leaves abundant in whorls about the middle or lower part of the stem, lanceolate or lance-oblong. Flowers several, large, yellow or red, in an umbel-like cluster beneath the terminal crown of leaves. Cultivated from Europe.

XI. ERYTHRONIUM L.

Nearly stemless herbs, arising from rather deeply buried bulbs. Leaves 2, long and smooth, with underground petioles. Scape arising from between the bases of the leaves. Flower commonly single, nodding.

1. E. americanum Ker. Yellow Adder's-Tongue. Leaves mottled. Flowers handsome. Perianth light yellow. Style club-shaped; stigmas united.

2. E. albidum Nutt. White Dogtooth Violet. Leaves not much mottled. Perianth bluish-white. Stigmas 3, short and spreading.

XII. TULIPA L.

Herbs appearing stemless, from coated bulbs. Leaves sessile. Scape simple. Flower solitary, erect. Perianth bell-shaped. Stamens short, awl-shaped, with broadly linear anthers. Style short; stigma thick, 3-lobed; ovary and pod triangular.

1. T. Gesneriana L. Common Tulip. Leaves 3–6, ovate-lanceolate, close to the ground. Flower large, on a smooth peduncle, color red, yellow, white, or variegated. Cultivated from Asia Minor. Many garden varieties exist.

XIII. SCILLA L.

Perennial herbs, appearing stemless, from coated bulbs. Leaves linear. Flowers racemed on a scape, generally blue. Divisions of the perianth 1-nerved, parted almost to the base. Filaments 6, often broad at the base. Style slender, with a knob-like stigma. Ovary 3-angled, 3-celled.

1. S. sibirica Andr. Siberian Squill. Scapes 3–8 in. high, several from each bulb, 2–3-flowered. Leaves 2–4, narrowly strap-shaped. Flowers intense blue, short-peduncled, often nodding. Cultivated from Russia and Siberia.

XIV. CAMASSIA Lindl. (QUAMASIA)

Herbs appearing stemless, from coated bulbs. Leaves linear. Flowers racemed on a scape. Perianth of 6 blue or purple spreading sepals. Stamens with thread-like filaments, slightly perigynous. Style thread-like, ending in a knobbed stigma. Capsule 3-angled, 3-celled, several-seeded.

1. C. esculenta Robinson. WILD HYACINTH. Leaves keeled, weak, shorter than the scape. Flowers in a long-bracted raceme, pale blue. River bottoms and other damp, rich soil.

XV. ORNITHOGALUM L.

Herbs appearing stemless, from coated bulbs. Leaves linear, fleshy. Scape erect. Flowers in corymbs or racemes, bracted. Perianth segments 6, white, nerved, persistent. Stamens 6, hypogynous, slender; filaments flattened. Ovary sessile, 3-celled, few-ovuled. Fruit a roundish, 3-angled capsule, seeds black.*

1. O. umbellatum L. STAR OF BETHLEHEM. Bulb ovoid, membranous-coated. Leaves numerous, linear, fleshy; mid-vein nearly white, as long as the scape. Scape slender, 6–12 in. high. Flowers opening in sunshine, long-pediceled. Bracts linear-lanceolate, about as long as the pedicels. Perianth segments oblong-lanceolate, white with a green stripe on the back, twice the length of the stamens. Introduced from Europe; very common about old gardens.*

XVI. HYACINTHUS L.

Herbs appearing stemless, from coated bulbs. Leaves linear, fleshy. Flowers in an erect spike, pediceled, bracted. Perianth tubular below, lobed and spreading above. Stamens short, included. Style short; stigma knobbed; ovary 3-celled, many-ovuled.*

1. H. orientalis L. HYACINTH. Leaves lance-linear, thick and fleshy, smooth. Scape erect, many-flowered. Segments united about half their length, white, blue, or red. Filaments very short. Ovary rarely maturing seed. Common in cultivation.*

XVII. YUCCA L.

Plants with woody and leafy stems. Leaves numerous, rigid, spine-pointed, persistent. Flowers in large terminal racemes

or panicles, bracted, nodding. Perianth bell-shaped; segments 6, nearly alike, deciduous. Stamens 6; filaments thickened above, often papillose; anthers small. Ovary sessile, 3-celled or becoming 6-celled, 3-angled, many-ovuled. Fruit an oblong, 3-angled, many-seeded, dehiscent capsule, or fleshy and indehiscent.*

1. Y. glauca Nutt. BEAR GRASS, SOAP WEED. Stem very short. Leaves basal, long, straight and slender, stiff, sharp-pointed, the margins white and with a few thread-like filaments, $\frac{1}{4}$–$\frac{1}{2}$ in. wide. Flowers racemed, greenish-white, globose or oblong, bell-shaped. Style green; capsule large, oblong, six-sided. Dry soil W.

2. Y. filamentosa L. SPANISH DAGGER. Stem stout, 4–12 in. high. Leaves linear or linear-lanceolate, slender-pointed, narrowed above the spreading and clasping base, spreading or recurved, smooth, with loose, thread-like filaments on the margins. Panicle elongated, with bract-like leaves on the scape, widely branched, downy-hairy above, 3–6 ft. high. Perianth white, bell-shaped, 2 in. wide. Capsule oblong, angles rounded, sides furrowed, at length 3-valved and dehiscent. In sandy soil, and often cultivated for ornament.*

XVIII. ASPARAGUS L.

Stem from fleshy, fibrous roots, erect, branched; branches slender, with thread-like branchlets in the axils of scales which take the place of leaves. Flowers small, solitary or racemed. Perianth 6-parted; segments distinct or slightly united. Stamens 6, perigynous; filaments thread-like. Ovary 3-celled, 6-ovuled; style short, slender; stigmas 3, recurved. Fruit a berry.*

1. A. officinalis L. ASPARAGUS. Stem succulent and simple, with fleshy scales when young; becoming taller, more woody, and widely branched, when old. Flowers axillary, solitary, or 2 or 3 together on slender, jointed, drooping pedicels, greenish; segments linear. Berry red, few-seeded. Introduced from Europe, common in cultivation, and often escaped.*

XIX. SMILACINA Desf. (VAGNERA)

Perennial, simple-stemmed herbs, with rootstocks. Leaves usually sessile, nerved, alternate. Flowers white, in a terminal raceme. Perianth spreading, 6-parted. Stamens 6, somewhat perigynous; filaments slender; anthers short, facing inward.

Ovary 3-celled, 6-ovuled; style short and stout, with a somewhat 3-lobed stigma. Fruit a 1–2-seeded berry.

1. S. racemosa Desf. False Spikenard. A showy plant with curved stem 1–3 ft. high, downy throughout. Leaves abundant, oval or ovate-lanceolate, taper-pointed. Flowers small, in a compound raceme. Berries pale red, speckled with dark red or purple. Moist thickets.

2. S. stellata Desf. Plant 1 ft. or less in height, nearly smooth. Leaves broadly lanceolate, acute, clasping. Flowers few, larger than in No. 1, in a simple raceme. Berries very dark red. Along river banks.

XX. MAIANTHEMUM Wiggers. (UNIFOLIUM)

Stem low. Leaves 2–3, lanceolate or ovate, with a heart-shaped base. Flowers small, white, solitary or in a simple raceme. Perianth 4-parted. Stamens 4. Ovary 2-celled; stigma 2-lobed.

1. M. canadense Desf. Two-Leaved Solomon's Seal, Wild Lily of the Valley. Plant 3–6 in. high. Leaves very short-petioled. Fruit a globular or ovoid berry, whitish, with brownish-red blotches. Woods and shaded banks N.

XXI. STREPTOPUS Michx.

Herbs with forking stems from a creeping rootstock. Leaves clasping. Flowers small, borne singly or in pairs on peduncles which arise above the leaf axils and which are sharply bent or twisted near the middle. Anthers arrow-shaped. Ovary 3-celled, ripening into a red, many-seeded berry.

1. S. amplexifolius DC. Liver Berry. Stem smooth, 2 ft. or more high. Leaves smooth-margined. Flowers greenish-white. Damp woods.

2. S. roseus Michx. Liver Berry, Jacob's Ladder. Branches with a few bristly hairs. Lower leaves margined with fine bristles. Flowers reddish or purplish. Cold, damp woods N.

XXII. POLYGONATUM Hill. (SALOMONIA)

Rootstock creeping, jointed, scarred. Stems simple, erect, scaly below, leafy above. Leaves alternate, oval or oblong. Flowers on axillary, 1–4-flowered, drooping, jointed peduncles.

Perianth tubular, 6-cleft. Stamens 6, included, inserted about the middle of the tube; anthers arrow-shaped. Ovary 3-celled, many-ovuled; style slender; stigmas knobbed or 3-lobed. Fruit a few-seeded berry.*

1. **P. biflorum** Ell. HAIRY SOLOMON'S SEAL. Stem simple, erect, arched, nearly naked below, 1–2 ft. high. Leaves 2-ranked, sessile or clasping, 3–7-nerved, smooth above, pale and downy beneath. Peduncles short, 1–4, often 2-flowered. Perianth greenish, 1–2 in. long. Filaments thread-shaped, roughened. Berry dark blue. Shady banks.*

2. **P. commutatum** Dietrich. SMOOTH SOLOMON'S SEAL. Stem simple, stout, curving above, 3–8 ft. high. Leaves lanceolate to ovate, many-nerved, partly clasping, smooth on both sides. Peduncles nearly half as long as the leaves, 2–6-flowered. Perianth greenish-yellow, $\frac{3}{4}$ in. long. Filaments smooth. Berry blue, $\frac{1}{2}$ in. in diameter. In rocky woods and along streams.*

XXIII. CONVALLARIA L.

Low, smooth, apparently stemless, perennial herbs. Leaves 2, oblong, with long petioles, from a slender, creeping rootstock. Scape slender, angled, inclosed at the base by the leafstalks. Flowers racemed, white, drooping. Perianth bell-shaped, with recurved lobes. Stamens borne on the base of the perianth. Ovary 3-celled, ripening into a few-seeded red berry.

1. **C. majalis** L. LILY OF THE VALLEY. A familiar garden flower, cultivated from Europe, and also found wild in mountain woods from Virginia to Georgia.

XXIV. TRILLIUM L.

Low herbs, with the stem springing from a short rootstock. Leaves 3, large, netted-veined, in a whorl. Flower large, terminal. Perianth of 6 parts, the 3 sepals unlike the 3 petals in color and in texture. Stamens 6, with the linear anthers usually opening inward, longer than the filaments. Stigmas 3, sessile, spreading at the tips; ovary 3- or 6-angled, 3-celled, many-seeded. Fruit a roundish, many-seeded purple berry.

1. **T. sessile** L. Rootstock erect or ascending, corm-like. Stem slender, 1–8 in. high. Leaves broadly oval, obtuse or acute at the apex, rounded and sessile at the base, 3–5-nerved, smooth, bright

green, not mottled. Flowers sessile; sepals lanceolate, ⅔–1 in. long; petals purple, elliptical, about the length of the sepals. Stamens half the length of the petals. Styles elongated, straight. In rich woods.*

2. T. erectum L. Squawroot, Benjamin. Rootstock rather upright, large and stout. Leaves broadly diamond-shaped, tapering to a short point. Pedicel 1–3 in. long, not quite erect. Petals ovate to lanceolate, much broader than the sepals, of a rich brownish-purple or sometimes white or pale. Stigmas distinct, stout, and spreading. The disagreeable scent of the flower has given rise to several absurd popular names for it. In rich woods.

3. T. grandiflorum Salisb. Large-Flowered Wake-Robin. Rootstock horizontal, stem slender, 12–18 in. high. Leaves rhombic-ovate, taper-pointed at the apex, rounded and sessile or slightly peduncled at the base, smooth and with a bloom, 5–7-nerved, bright green. Peduncle longer than the erect or slightly declined flower. Sepals lanceolate-acute, 1–1½ in. long. Petals white, fading to pink, longer than the sepals. Stamens less than half the length of the petals. Style short; stigmas recurved. Fruit a black, roundish berry. In rich woods.*

4. T. cernuum L. Nodding Trillium. Stem 8–20 in. high. Leaves broadly rhombic or rhombic-ovate, 2–4 in. wide, taper-pointed, sessile or nearly so. Peduncle recurved beneath the leaves. Petals white or pink, wavy, somewhat recurved, as long as the sepals or a little longer. Stamens with filaments about equaling the anthers. Stigmas stout, recurved. Rich moist woods.

5. T. nivale Riddell. Dwarf White Trillium. Stem 2–4 in. high. Leaves petioled, oval to ovate. Flower white, erect. Petals ½–1¼ in. long, ovate-spatulate. Rich, damp woods, blooming with the very earliest spring flowers.

6. T. undulatum Willd. Painted Trillium. Stem 8–12 in. high. Rootstock oblique to the rest of the stem, rather small; roots long and fibrous. Leaves ovate, taper-pointed. Petals white, penciled at the base, with purple stripes, lance-ovate, somewhat recurved, wavy. Cold woods, especially N.

XXV. SMILAX L.

Mostly woody vines, usually with prickly stems, climbing by tendrils. Rootstock often large and tuberous. Leaves alternate, prominently nerved, netted-veined, petioled; stipules replaced by persistent tendrils. Flowers regular, diœcious, small, greenish, in axillary umbels. Perianth bell-shaped, segments 6. Stamens 6, distinct. Ovary 3-celled, 3–6-ovuled; stigmas 1–3, sessile or nearly so. Fruit a 1–6-seeded globose berry.

1. S. herbacea L. Carrion Flower. Stem herbaceous, erect, simple or branched, not prickly, 1–3 ft. high. Leaves few, ovate, acute, and mucronate at the apex, somewhat heart-shaped at the base, 5–7-nerved, thin, smooth above, downy below, the upper sometimes whorled and the lower bract-like; petiole short. Peduncles as long as the leaves, growing from below the petiole. Umbel many-flowered, flowers carrion-scented. Berry blue-black, 2–4-seeded. Dry, fertile soil.*

2. S. Walteri Pursh. Green-Brier. Stem low, with few prickles, 2–5 ft. long; branches slightly 4-angled, unarmed. Leaves oblong-lanceolate to oval, obtuse or acute at the apex, rounded or cordate at the base, 5-ribbed, smooth. Peduncles flattened, about as long as the petioles and pedicels. Berry bright red, ripening the first year. Wet pine barrens.*

3. S. rotundifolia L. Green-Brier, Cat-Brier, Dog-Brier, Horse-Brier, Wait-a-Bit. Stem green, strong; branchlets, and sometimes the branches, 4-angled, armed with stout hooked prickles. Leaves ovate or round-ovate, with a slightly heart-shaped base and an abruptly pointed tip. Berries black, with a bloom. Thickets, the commonest species N. E.

4. S. glauca Walt. Green-Brier. Stem cylindrical, slender, with scattered prickles, branches angled and usually without prickles. Leaves ovate or subcordate, pointed at the apex, mostly 5-nerved, smooth, white beneath, with a bloom, margin entire. Peduncle flattened, 2–3 times as long as the petiole, few-flowered. Berry black, 3-seeded. Margin of swamps.*

5. S. Bona-nox L. Bamboo Vine. Stem stout, cylindrical or slightly angled, scurfy when young, armed with numerous stout prickles. Branches 4-angled, usually unarmed. Leaves triangular, ovate, or often halberd-shaped, 5–7-ribbed, smooth on both sides and often discolored; margins usually fringed with fine prickles. Peduncles twice as long as the petioles, flattened. Umbels many-flowered; pedicels short. Berries 8–20 in a cluster, black, 1-seeded. In swamps and thickets.*

11. AMARYLLIDACEÆ. Amaryllis Family

Mostly smooth perennial herbs, from bulbs. Leaves basal, with no distinction between petiole and blade. Flowers borne on a scape, nearly or quite actinomorphic. Stamens 6. Style 1. Limb of the 6-parted, corolla-like perianth epigynous. Ovary 3-celled. Capsule 3-celled, several–many-seeded.

I. NARCISSUS L.

Scapes with 1–several flowers from a thin, dry spathe. Flowers with a cup-shaped or other crown on the throat of the perianth; tube of the perianth somewhat cylindrical, the 6 divisions of the limb widely spreading. Stamens 6, inserted in the tube.

1. N. Psuedo-Narcissus L. DAFFODIL, DAFFY, EASTER FLOWER. Scape short, bearing 1 large yellow flower; tube of perianth short and wide, crown with a crimped margin. Cultivated from Europe.

2. N. Tazetta L., var. **orientalis.** CHINESE SACRED LILY. Bulb large, often with many smaller ones attached to its base. Scape 1 ft. or more high. Flowers several, umbeled, fragrant. Perianth white or nearly so, the crown rather spreading, finely scalloped, yellow or orange. Cultivated from China.

3. N. poeticus L. POET'S NARCISSUS. Scape 1-flowered. Perianth pure white, the crown very narrow, edged with pink. Cultivated from S. Europe.

II. ZEPHYRANTHES Herb. (ATAMOSCO)

Stemless, from a coated bulb. Leaves linear, fleshy. Scape erect, 1–few-flowered. Flowers large, erect, or declined, subtended by a 1–2-leaved spathe. Perianth 6-parted, naked in the throat; tube short, segments petal-like, spreading. Stamens free, anthers versatile. Ovary 3-celled, many-ovuled; style elongated, declined; stigma 3-cleft. Fruit a many-seeded, 3-valved capsule; seeds black, compressed, or angled.*

1. Z. Atamasco Herb. ATAMASCO LILY. Bulbs about 1 in. in diameter. Leaves narrow, concave above, smooth, usually longer than the scape. Scape 6–12 in. high, 1-flowered. Spathe 1-leaved, 2-cleft. Flowers 2–3 in. long, white, tinged with pink or purple, bell-shaped, short-peduncled. Stamens longer than the tube, shorter than the style. Capsule depressed-globose, seeds angled. In rich, damp soil, often cultivated.*

III. HYPOXIS L.

Small, apparently stemless herbs. Leaves grass-like, hairy, from a solid bulb. Scapes thread-like, few-flowered. Perianth 6-parted, wheel-shaped, the 3 outer divisions greenish on the outside, the whole perianth withering on the pod. Seeds numerous.

1. H. hirsuta Coville. Star Grass. Leaves longer than the scape, both sparsely set with long, soft hairs. Scape 3–8 in. high. Flowers 1–4, about ½ in. across, yellow. Common in meadows and dry woods.

12. IRIDACEÆ. Iris Family

Perennial herbs from bulbs, corms, or rootstocks. Leaves 2-ranked, equitant. Flowers bisexual, often actinomorphic, each subtended by two bracts. Perianth 6-parted, the segments epigynous in 2 series of 3 each, equal, or the inner ones smaller. Stamens 3, distinct or united, opposite the outer segments. Ovary forming a 3-celled, 3-angled, 3-valved, many-seeded, dehiscent capsule.*

I. CROCUS L.

Leaves springing from the corm. Flowers sessile on the corm. Tube of the perianth very long and slender, its divisions all alike or nearly so. Stigmas 3-cleft.

1. C. vernus All. Spring Crocus. Leaves linear. Stigmas short. Flowers white, blue, or purple. Our earliest garden flower. Cultivated from Europe.

II. IRIS L.

Rootstock thick, creeping, branching, horizontal, sometimes tuberous. Stems erect, simple or branched. Leaves linear or sword-shaped. Flowers showy, the outer perianth segments spreading or recurved, often bearded within, the inner segments usually smaller and erect. Stamens inserted in the base of the outer segments. Style deeply 3-parted (Fig. 8), the divisions broad and petal-like, covering the stamens. Fruit an oblong or oval, 3- or 6-angled, many-seeded capsule (Fig. 9).*

1. I. versicolor L. Large Blue Flag. Rootstock thick, horizontal. Stem cylindrical, smooth, simple or branched, leafy, 2–3 ft. high. Leaves linear, sword-shaped, finely nerved, with a bloom, the lower 1½–2 ft. long, the upper shorter. Bracts longer than the pedicels. Flowers terminal, single or few together, blue variegated with white, yellow, and purple; perianth segments not bearded, the inner ones smaller. Ovary 3-angled, longer than the inflated perianth tube. Capsule oblong, slightly lobed; seeds 2 rows in each cell. In wet places.*

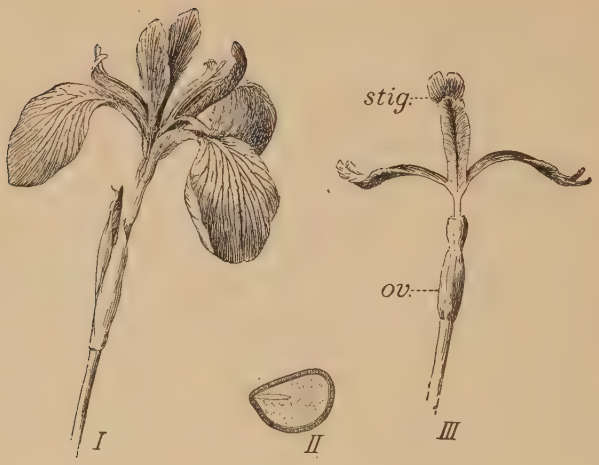


FIG. 8. Iris

I, flower. II, seed, longitudinal section. III, flower with outer segments of perianth removed: *stig.*, stigma, *ov.*, ovary

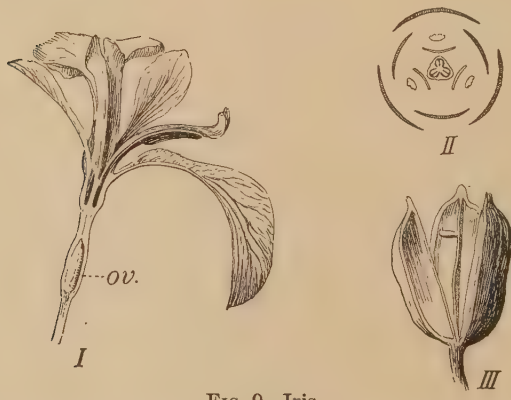


FIG. 9. Iris

I, flower, longitudinal section: *ov.*, ovary. II, diagram showing stigmas opposite the stamens; III, capsule, splitting between the partitions

2. I. prismatica Pursh. Slender Blue Flag. Rootstock rather slender, with tuber-like thickened portions. Stem slender, cylindrical, usually unbranched, 1–3 ft. high. Leaves 2–3 in number, narrowly linear, $\frac{1}{8}$–$\frac{1}{4}$ in. wide. Flowers slender-peduncled, solitary or in twos, blue with yellow veins, the perianth tube beardless and crestless. Ovary 3-angled; capsule sharply 3-angled. Marshy soil near the coast.

3. I. fulva Ker. Yellow Flag. Rootstock fleshy. Stem simple or branched, grooved, 1-angled below, bearing 2–3 leaves, 2–3 ft. high. Leaves linear, sword-shaped, with a bloom, shorter than the stem; bracts small. Pedicels short, flowers axillary and terminal, dull yellow or reddish-brown, variegated with blue and green, perianth segments not bearded. Style branches but little exceeding the stamens; ovary about as long as the inflated perianth tube; capsule ovate, 6-angled. Swamps and wet places.*

4. I. germanica L. Fleur-de-Lis. Rootstock thick, matted. Stem stout, branched, leafy, 2–3 ft. high. Leaves strap-shaped, acute, erect, shorter than the stem; bracts scarious. Flowers sessile, large and showy, blue variegated with white and yellow, sometimes nearly all white; outer segments large, recurved, bearded, the inner narrower, erect, or arched inward. Introduced from Europe; common in gardens and naturalized in many places.*

III. SISYRHINCHIUM L.

Small, grass-like perennials. Stems erect, flattened, or winged. Roots fibrous. Leaves linear or lanceolate. Flowers small, blue, quickly withering, in terminal 2-bracted umbels. Perianth corolla-like, of 6 bristle-pointed segments; tube nearly or wholly lacking. Stamens 3, completely monadelphous. Stigmas 3, thread-like. Fruit a nearly globular, 3-angled capsule. Species too difficult for the beginner; all commonly known as Blue-Eyed Grass.

13. ORCHIDACEÆ. Orchis Family

Perennial herbs with simple stems, often arising from bulbs or tubers. Leaves simple, usually alternate and entire. Flowers bisexual, generally showy, epigynous, zygomorphic, and often of extraordinary shapes. Perianth of 6 divisions. Stamens 1 or 2, united with the pistil; pollen of comparatively

few grains, held together in masses by cobweb-like threads. Ovary 1-celled, containing many (sometimes more than a million) very minute ovules.

The family is a difficult one, and most of the genera are so rare that specimens should not be collected in large numbers for class study. Two of the most familiar genera are *Cypripedium*, or Lady's Slipper, and *Spiranthes*, or Lady's Tresses. Many of the genera are tropical air plants.

SUBCLASS II. DICOTYLEDONOUS PLANTS

Stems composed of bark, wood, and pith; the fibro-vascular bundles in rings; in woody stems which live over from year to year, the wood generally in annual rings, traversed at right angles by medullary rays. Leaves netted-veined. Parts of the flower usually in fours or fives. Cotyledons 2 (rarely none).

14. SALICACEÆ. Willow Family

Dicœcious trees or shrubs, with flowers in catkins, destitute of floral envelopes. Fruit a 1-celled pod, with numerous seeds, provided with rather long and silky down, by means of which they are transported by the wind.

I. SALIX L.

Shrubs or trees, branches usually very slender. Buds with single scales. Leaves usually long and narrow; stipules sometimes leaf-like or often small and soon deciduous. Bracts of the catkins entire. Staminate catkins erect or drooping (Fig. 10); staminate flowers with 2–10, mostly 2, distinct or united stamens. Pistillate catkins usually erect (Fig. 10); flowers with a small gland on the inner side of the bract; stigmas short, 2-lobed. Capsule 2-valved.*

[Thirty or more species of willow are found growing wild in the northeastern and north central states, but they are very hard, even for botanists, to identify.]

1. S. nigra Marsh. Black Willow. A small tree with very brittle branches. Leaves elliptical or narrowly lanceolate, acute at each end, serrate, short-petioled, downy when young and becoming smooth with age, 2–3 in. long; stipules persistent or deciduous. Staminate catkins 1–2 in. long; the pistillate 2–4 in. long. Stamens 3–7, distinct; filaments soft-hairy below. Capsule twice the length of the pedicel, ovate, taper-pointed, pointed by the prominent style. Along streams and borders of marshes.*

2. S. lucida Muhl. Shining Willow. A large shrub or sometimes a bushy tree 20 ft. high, with smooth bark, yellowish-brown and shining on the twigs. Leaves varying from ovate to lanceolate, usually with very slender tapering points, sharply and finely serrate, firm, green, and glossy on both sides, 3–5 in. long; stipules small, oblong, usually persistent. Catkins borne on short leafy branches, the staminate ones stout, 1–1½ in. long, the pistillate ones slender, 1½–2 in. long, lengthening in fruit to 3–4 in. Stamens usually 5. Capsule narrowly ovoid or cylindrical, pointed, smooth, and shining. Banks of streams, lakes, and swamps. One of the most beautiful willows from the showiness of the staminate catkins and the large glossy leaves.

Fig. 10. White willow (*Salix alba*)

A, staminate catkin, natural size; *B*, pistillate catkin, natural size; *C*, a staminate flower, magnified; *D*, a pistillate flower, magnified. (After Cosson and De Saint-Pierre)

3. S. alba L. White Willow, Yellow Willow. A spreading tree 50–80 ft. high, with rough gray bark, yellowish-green on the twigs. Leaves lanceolate, narrowed at the base, with long tapering points, gray or silky-downy on both sides when young, the upper surface (especially in Var. *vitellina*) becoming smooth when old, 2–4 in. long; stipules ovate-lanceolate, deciduous. Catkins on short leafy branches, the pistillate ones slender, cylindrical, 1¼–3½ in. long. Stamens usually 2. Capsule ovoid, pointed. Cultivated from Europe (especially Var. *vitellina*), and

occasionally escaped from cultivation along streams. Very variable and with many hybrids.

4. S. babylonica L. Weeping Willow. A spreading tree, sometimes 60 ft. or more in height, with drooping branches. Leaves narrowly lanceolate, taper-pointed, serrate, slightly downy when young and becoming smooth with age, green above, pale beneath, often 5–7 in. long; petioles short, glandular. Catkins on short lateral branches. Stamens 2. Style almost none. Capsule sessile, smooth. Introduced and cultivated for ornament.

5. S. cordata Muhl. Heart-Leaved Willow. A shrub 4–10 ft. high, with twigs finely downy or smooth. Leaves oblong-lanceolate, taper-pointed, finely and sharply serrate, often tapering but frequently obtuse or somewhat heart-shaped at the base, finely downy when young (especially on the midrib) but smooth when old; sometimes 5 in. long; stipules usually large and conspicuous, unequal-sided, finely serrate, generally persistent. Catkins with bracts at the base, opening earlier than the leaves, the staminate ones very silky, less than 1 in. long, the fertile ones in fruit $1\frac{1}{2}$–$2\frac{1}{2}$ in. long. Capsules narrowly ovoid, pointed. In wet soil and along streams, very variable and widely distributed.

6. S. discolor Muhl. Glaucous Willow, Pussy Willow. A low tree, sometimes 20 ft. or more in height, with light greenish-brown or reddish-brown bark. Leaves oblong-lanceolate, tapering at both ends, finely and irregularly toothed or nearly entire, on slender petioles, smooth and firm, bright green above, smooth or silvery white below, 3–5 in. long; stipules often leaf-like, unsymmetrical, usually deciduous. Staminate catkins very white and silky, oblong-cylindrical, 1 in. or more long, appearing much earlier than the leaves; pistillate catkins $1\frac{1}{2}$–$2\frac{1}{2}$ in. or more long. Stamens 2, with long, slender filaments. Capsule cylindrical or nearly so, long-beaked. Common in wet meadows or along streams and swamps.

II. POPULUS L.

Trees with prominent scaly buds, twigs more or less angled. Leaves usually long-petioled.

Flowers borne in long, drooping catkins, which appear before the leaves; scales of the catkins irregularly cut toward the tip. Stamens 8–30 or more. Stigmas 2–4. Capsules opening early by 2–4 valves.

1. P. alba L. Silver-Leaved Poplar, White Poplar. A large tree, sometimes more than 100 ft. high, with smooth greenish-gray bark. Leaves broadly ovate, rhombic-oval or nearly orbicular, lobed

or very coarsely toothed, densely white-downy beneath. Cultivated as a shade tree and sometimes found growing spontaneously.

2. P. tremuloides Michx. American Aspen, Quaking Asp. A tree 20–60 ft. high, with greenish-white bark. Leaves roundish, heart-shaped, abruptly pointed, with small regular teeth. Leafstalk long, slender, and flattened at right angles to the broad surfaces of the leaf, causing it to sway edgewise with the least perceptible breeze. Common especially N.

3. P. grandidentata Michx. Large-Toothed Poplar. A tree 60–80 ft. high, with rather smooth gray bark. Leaves 3–5 in. long, roundish-ovate and irregularly sinuate-toothed; when young completely covered with white silky wool, which is shed as soon as the leaf matures. The petiole is somewhat flattened, but not nearly as much so as that of the preceding species. Rich woods N.

4. P. heterophylla L. Swamp Poplar. Branches only slightly angled. Leaves ovate, mostly obtuse at the apex, rounded or subcordate at the base, serrate with obtuse teeth, densely woolly when young, but becoming smooth with age; petioles cylindrical. Pistillate catkins smooth, erect or spreading, loosely flowered. Capsule ovoid, usually shorter than the pedicel. Common in river swamps. A large tree with soft light wood, which is often used in making cheap furniture.*

5. P. deltoides Marsh. Cottonwood. A large and very rapidly growing tree, 75–100 ft. or more high, often with a markedly excurrent trunk. Leaves large and broadly triangular, with crenate-serrate margins and long, tapering, acute tips; petioles long and considerably flattened. The numerous pediceled capsules are quite conspicuous when mature, and the air is filled with the downy seeds at the time when the capsules open. Common W., especially along streams, and planted as a shade tree.

15. MYRICACEÆ. Bayberry Family

Shrubs with alternate, simple, resinous-dotted leaves; monœcious or dicœcious. Flowers in short, bracted catkins; perianth none. Staminate flowers 2–10, stamens hypogynous; pistillate flowers surrounded by 2–6 scales. Ovary 1-celled; style short; stigmas 2.

I. MYRICA L.

Shrubs or small trees with the branches clustered at the end of the growth of the previous season. Leaves short-petioled, entire, lobed or toothed, the margin usually revolute,

without stipules. Perianth none. Staminate flowers in oblong or cylindrical catkins; stamens 2–10, with the filaments united below. Pistillate flowers surrounded by a cup of 2–6 scales; ovary solitary, becoming a 1-celled, roundish drupe or nut, often covered with waxy grains. Whole plant usually fragrant.*

1. M. carolinensis Mill. Waxberry, Bayberry. A spreading shrub or small tree; young branches downy. Leaves lanceolate or oblong-lanceolate, entire or sometimes serrate near the mostly obtuse apex, smooth or downy on the veins beneath, tapering into a short petiole. Flowers mostly dicœcious. Staminate catkins numerous, stamens 4. Pistillate catkins small, bracts slightly 3-lobed, scales of the ovary 4, fringed with hairs; stigmas 2. Fruit very abundant, incrusted with white wax, $\frac{1}{8}$–$\frac{1}{6}$ in. in diameter, sometimes persistent for 2 or 3 years. Common on wet soils, especially near the coast.*

2. M. asplenifolia L. Sweet Fern. A shrub 2 ft. or less in height, with brown twigs. Leaves fern-like, linear-lanceolate, 20–30-lobed, 3–5 in. long and very fragrant. Often monœcious. Staminate catkins cylindrical; pistillate catkins globular. Ovary surrounded by 8 long, linear, awl-shaped, hairy and glandular scales which encircle the ripened fruit. Nut nearly ovoid, smooth, small, but eaten by children.

16. JUGLANDACEÆ. Walnut Family

Trees with alternate, odd-pinnate leaves without stipules. Flowers monœcious, the staminate in long and drooping catkins; stamens few or many; calyx 2–6-parted. Fertile flowers solitary or in small clusters; calyx 3–5-lobed, minute petals sometimes present. Ovary inferior, 1-celled or incompletely 2–4-celled. Fruit (strictly speaking a drupe) with a dry husk inclosing a bony nut.*

I. JUGLANS L.

Staminate catkins cylindrical, solitary, borne on wood of the previous year; stamens numerous, filaments short; calyx 4–6-parted. Pistillate flowers single or a few together on a short peduncle at the base of the growth of the season. Calyx 4-parted. Petals 4, minute, epigynous. Styles 2, short, plumose. Fruit large, roundish or oval, husk fibrous-fleshy, becoming dry, indehiscent; nut bony, very rough.*

1. J. cinerea L. BUTTERNUT. Leaflets 15–19, ovate-lanceolate, taper-pointed at the apex, rounded or slightly unsymmetrical at the base, serrate, downy beneath; petioles, branchlets, and fruit clothed with short, sticky hairs. Fruit often somewhat in clusters, oblong, large. More common northward. Wood less valuable and nut less oily than the black walnut. The English walnut (*J. regia*) is occasionally seen in cultivation. It has 7–11 leaflets and a nearly smooth nut.*

2. J. nigra L. BLACK WALNUT. Leaflets 13–21, ovate-lanceolate, serrate, taper-pointed, somewhat cordate or oblique at the base, nearly smooth above, downy beneath; petioles minutely downy. Fruit usually single, roundish, about 2 in. in diameter. On rich soil, rare near the coast. One of the most valuable of our native trees, the wood being very durable and highly prized for cabinet work.*

II. CARYA Nutt. (HICORIA)

Leaflets serrate. Staminate catkins usually in threes on a common peduncle, or sometimes sessile at the base of the growth of the season; calyx 2–3-parted; stamens 3–10, filaments short. Pistillate flowers 2–5 in terminal clusters; calyx 4-parted; petals none; styles 2 or 4, fringed. Fruit somewhat globular, husk separating more or less completely into 4 valves; nut smooth or angled.*

1. C. illinoensis K. Koch. PECAN. A large tree with rough gray bark, young twigs and leaves downy, nearly smooth when mature. Leaflets 11–15, oblong-lanceolate, acuminate, serrate, scythe-shaped. Staminate catkins nearly sessile, 5–6 in. long. Husk of fruit thin; nut oval or oblong, thin-shelled. River bottoms. Rarely native east of the Mississippi River, but widely planted for its fruit.*

2. C. ovata K. Koch. SHELLBARK HICKORY. A large tree with bark scaling off in long plates; young twigs and leaves downy, becoming smooth with age. Leaflets 5, the lower ones oblong-lanceolate, the upper one longer and obovate, taper-pointed at the apex, narrowed to the sessile base. Inner bud scales becoming large and conspicuous. Staminate catkins in threes. Fruit globose, husk thick, splitting into four sections; nut white, compressed, 4-angled, pointed, thin-shelled. On rich soil; more common N. Wood strong and elastic, but not durable when exposed.*

3. C. laciniosa Loud. BIG SHELLBARK, KING NUT, BULL NUT. A tree 70–90 ft. high, with shaggy bark. Leaflets 7 or 9, the terminal one nearly sessile. Fruit large, ovoid or nearly so, 4-grooved toward the outer end, the husk very thick, nut pointed at each end, $1\frac{1}{2}$–2 in.

long, thick-shelled, with a very sweet kernel. Wood hard and heavy. Common in rich, damp soil W.

4. C. alba K. Koch. Mocker Nut, White-Heart Hickory. A large tree 70–100 ft. high, with close, rough bark; catkins, twigs, and under surfaces of the leaves downy and resinous-scented when young. Leaflets 7–9, oblong-lanceolate or obovate-lanceolate, taper-pointed. Fruit globose or nearly so, with a very thick, hard husk; nut with 4 ridges toward the apex, very thick-shelled, with a small, sweet kernel. On rich hillsides. Wood much like that of *C. ovata*.

5. C. cordiformis K. Koch. Pignut, Swamp Hickory. A medium-sized tree, with rather smooth bark. Leaflets 7–11, lanceolate or oblong-lanceolate. Fruit not large, husk thin; nut globular, with a short point, very thin-shelled; kernel extremely bitter. Moist soil, common in the Middle States.

17. BETULACEÆ. Birch Family

Trees or shrubs with alternate, simple, petioled leaves, with usually deciduous stipules. Flowers monœcious in cylindrical or subglobose catkins. Staminate catkins drooping; flowers 1–3 in the axil of each bract; calyx none or membranous and 2–4-parted; stamens 2–10, distinct. Pistillate catkins drooping, spreading, or erect and spike-like; flowers with or without a calyx; ovary solitary, 1–2-celled; ovules 1–2 in each cell. Fruit a 1-celled nut or a key.*

I. CORYLUS L.

Shrubs with prominently veined, cut-toothed leaves, which are folded lengthwise in the bud. Flowers expanding before the leaves. Staminate flowers in slender, drooping catkins; stamens 8, anthers 1-celled. Fertile flowers several in a cluster or in very short catkins at the ends of the twigs of the season; ovary incompletely 2-celled; style short; stigmas 2; bractlets 2, becoming enlarged and inclosing the single bony nut at maturity.*

1. C. americana Walt. Hazelnut. A shrub 2–5 ft. high; young twigs and petioles covered with brownish, stiff hairs. Leaves not very thin, round-cordate, acute or slightly taper-pointed, irregularly toothed, nearly smooth above, downy below. Involucre longer than

the nut and partially inclosing it, glandular-hairy. Nut subglobose, pointed, edible. On rich soil, borders of meadows and fields, and in oak openings.

2. C. rostrata Ait. BEAKED HAZELNUT. A shrub 4–8 ft. high. Young twigs near ends smooth. Leaves thin, little if at all heart-shaped, doubly serrate or incised, taper-pointed, stipules linear-lanceolate. Involucre completely covering the nut and prolonged into a beak beyond it. Common N. [The latter species is not nearly as widely distributed as the former; they cannot be readily distinguished from each other until the fruit is somewhat mature. The principal points of difference discernible before the fruit is nearly mature are the hairy twigs of No. 1 and the smooth ones of No. 2, and the fact that No. 1 has buds rounded at the apex and more slender and longer staminate catkins, while No. 2 has buds acute at the apex and thicker and shorter staminate catkins.]

II. OSTRYA Scop.

Small trees with gray bark and very hard wood. Leaves open and concave in the bud and somewhat plaited on the veins. Staminate flowers on slender, drooping catkins, sessile at the end of the growth of the previous season; stamens 3–12, subtended by a bract; filaments forked; anthers hairy. Pistillate flowers surrounded by a tubular bractlet, which becomes large and bladder-like at maturity. Fruit a small, pointed, smooth nut; mature catkins hop-like.*

1. O. virginiana K. Koch. A small tree with brownish, furrowed bark. Leaves ovate, acute, doubly serrate, often inequilateral at the base, short-petioled. Staminate and fertile catkins 2–3 in. long. In rich woods. Often known as "ironwood" and "leverwood." *

III. CARPINUS L.

Trees with thin, straight-veined leaves, which are folded in the bud. Flowers appearing before the leaves. Staminate flowers in slender, drooping catkins, sessile at the end of the growth of the previous season; stamens 3–12, subtended by a bract; filaments forked; anthers hairy. Pistillate catkins spike-like, each pair of flowers subtended by a deciduous bract, and each flower by a persistent bractlet, which becomes large and leaf-like in fruit; ovary 2-celled, 2-ovuled; stigmas 2, thread-like. Fruit a small, angular nut.*

1. C. caroliniana Walt. HORNBEAM. A small tree with smooth and close gray bark; twigs slender. Leaves ovate-oblong, acute or taper-pointed, sharply and doubly serrate, the straight veins terminating in the larger serrations; downy when young and soon becoming smooth. Staminate catkins 1–1½ in. long. Pistillate catkins long-peduncled, 8–12-flowered; bractlets becoming nearly 1 in. long, cut-toothed, the middle tooth much longer than the others. In rich, moist woods. Often known as "blue beech" and "ironwood."*

IV. BETULA L.

Trees with slender, aromatic twigs, and thin, usually straight-veined leaves. Staminate catkins drooping, flowers usually 3 in the axil of each bract; stamens 4, short; anthers 1-celled. Pistillate catkins erect, flowers 2 or 3 in the axil of each bract; ovary sessile, 2-celled; styles 2; bracts 3-lobed; perianth none. Nut broadly winged.*

1. B. lenta L. CHERRY BIRCH. Leaves ovate or oblong-ovate, acute, heart-shaped, finely and doubly serrate, silky when young; petioles about ½ in. long. Staminate catkins clustered, 3–4 in. long. Pistillate catkins sessile, about 1 in. long; cylindrical bracts spreading, acute, smooth. River banks, especially N. A large tree, with aromatic twigs. The oil contained in the bark and twigs is distilled and used as a substitute for wintergreen.*

2. B. lutea Michx. f. YELLOW BIRCH. A large forest tree, sometimes 60–90 ft. high, with yellowish or silver-gray bark, which peels off in extremely thin layers. Leaves ovate or nearly so, usually taper-pointed, rounded or sometimes almost heart-shaped at the base, sharply and finely serrate, somewhat downy on the veins beneath, 3–5 in. long. Staminate catkins 3–3½ in. long; pistillate catkins about ⅔ in. long. Rich woods N., also southward in the mountains.

3. B. nigra L. RIVER BIRCH, RED BIRCH. A medium-sized tree with reddish-brown bark. Leaves rhombic-ovate, acute at the apex, acute or obtuse at the base, sharply and doubly serrate, white-downy below, becoming smoother with age, petioles short. Staminate catkins 2–3 in. long. Pistillate catkins 1–1½ in. long, peduncles short, bracts nearly equally 3-cleft, woolly. River banks, especially S. and W.*

4. B. populifolia Marsh. GRAY BIRCH. A tall shrub or slender, straggling tree, 15–30 ft. high, seldom growing erect, often several trunks springing from the ground almost in contact and slanting away from each other. Leaves triangular, with a long taper point and truncate base, unevenly twice serrate, with rather long, slender petioles, which allow the leaves to quiver like those of the aspen.

Bark scaling off in white strips and layers, but not in nearly as large sheets as that of the rarer canoe birch (*B. papyrifera*). The commonest birch of New England.

5. B. alba L. European White Birch, Cut-Leaved Birch. A tree 50–60 ft. high, often with drooping branches. Leaves triangular-ovate, truncate, rounded or somewhat heart-shaped at

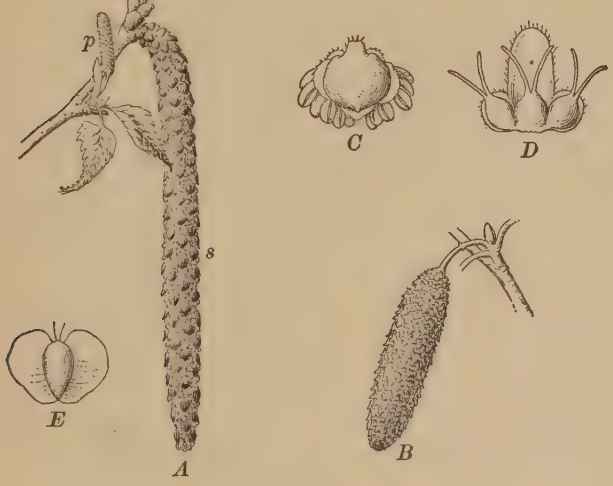


Fig. 11. Gray birch (*Betula populifolia*)

A, catkins, natural size: *s*, staminate; *p*, pistillate. *B*, cluster of ripened fruits; *C*, bract with three staminate flowers; *D*, bract with three pistillate flowers; *E*, fruit. (*B*, *C*, *D*, *E*, somewhat magnified)

the base, not strongly taper-pointed except in the cut-leaved form. Commonly cultivated from Europe. Resembles No. 4, but has whiter bark and (the weeping form) much more slender branches.

Var. **papyrifera.** Canoe Birch, Paper Birch. A large tree, often 60–70 ft. high, with chalky-white papery bark, peeling off in large thin sheets. Leaves ovate, acute or taper-pointed, coarsely serrate or dentate, but entire at the base, dark green and usually without glands on the upper surface, on the lower surface light yellowish-green and nearly smooth, but with tufts of hairs in the

forks of the veins and numerous black glands, 2–3 in. long, with slender petioles. Staminate catkins 3–4 in. long; pistillate catkins 1–1½ in. long, peduncles 2-bracted. Rich soil on hillsides, along streams, and near lakes and swamps, N. and N.E. The beautiful bark is much used by the Indians for canoes, for basket making, and for other purposes.

V. ALNUS, Hill

Shrubs or small trees. Leaves petioled, serrate. Flower buds stalked, appearing the previous season; staminate catkins racemed, drooping; flowers 3–6 in the axil of each bract, subtended by 1–2 bractlets; perianth 4-parted; stamens 4; filaments short. Pistillate catkins erect; flowers 2–3 in the axil of each bract; perianth replaced by 2–4 minute bractlets which are adherent to the bract. Ovary 2-celled; styles 2. Fruit a winged or angled nut; bracts of the pistillate flowers somewhat fleshy, persistent, becoming woody in fruit.*

1. **A. incana** Mœnch. Speckled Alder. A shrub 8–20 ft. high. Leaves broadly oval or ovate, rounded at the base, sharply (sometimes doubly) serrate, white and usually downy beneath. Fruit round. Forming thickets by streams, very common N.

2. **A. rugosa** Spreng. Smooth Alder. A shrub or small tree with smooth bark. Leaves obovate, rounded or obtuse at the apex, acute at the base, sharply and minutely serrate, smooth above, downy beneath, petioled; stipules oval, deciduous. Staminate catkins 2–4 in. long; fruiting catkins ovoid, short-peduncled. Fruit ovate, wingless. Banks of streams and borders of marshes, ranging far S. Leaves often persistent during the winter.*

18. FAGACEÆ. Beech Family

Trees or shrubs. Leaves alternate, simple, pinnately veined; stipules deciduous. Flowers monœcious, the staminate in heads, or in drooping, spreading, or erect catkins; calyx minute; petals none; stamens 4–20. Pistillate flowers solitary or in small clusters, each flower subtended by more or less united bracts, which at maturity form a cup or bur; calyx minutely toothed; petals none; ovary 2–7-celled, but becoming 1-celled. Fruit a 1-seeded nut.*

I. FAGUS L.

Trees with smooth, close, ash-gray bark, and slender, often horizontal, branches. Staminate flowers in long, slender-peduncled, roundish clusters; calyx bell-shaped, 4–6-cleft; stamens 8–12; anthers 2-celled. Pistillate flowers solitary or more often in pairs, peduncled, surrounded by a 4-lobed involucre and numerous linear bracts; ovaries 3-celled, with 2 ovules in each cell, but usually only 1 ovule maturing in each ovary; styles 3, thread-shaped. Fruit a thin-shelled, 3-angled nut.*

1. F. grandifolia Ehrh. BEECH. Large trees. Leaves oblong-ovate, taper-pointed at the apex, serrate, straight-veined, very white-silky when young, nearly smooth with age. Involucre densely covered with short recurved spines. Nuts thin-shelled, edible. Common on damp soil everywhere. The wood is very hard, tough, and close-grained, and is especially valuable for the manufacture of small tools.*

2. F. sylvatica L. The European beech is occasionally found planted as a shade tree. The variety known as the copper beech is most usual, and is readily recognized by its dark, crimson-purple leaves.

II. CASTANEA Hill

Trees or shrubs with rough, gray, rather close bark. Leaves straight-veined, undivided, prominently toothed. Flowers appearing later than the leaves. Staminate catkins erect or spreading, loosely flowered, flowers several in the axil of each bract; calyx 4–6-parted; stamens 8–16. Pistillate flowers at the base of the staminate catkin or in small separate clusters, usually 3 in each involucre; ovary 4-celled, surrounded by 5–12 abortive stamens. Fruit a 1-celled nut inclosed in the greatly enlarged and very prickly involucre.*

1. C. dentata Borkh. AMERICAN CHESTNUT. A large tree, bark somewhat rough, and splitting into longitudinal plates. Leaves oblong-lanceolate, taper-pointed at the apex, usually acute at the base, coarsely and sharply serrate with ascending teeth, smooth, dark green above, lighter below; petioles stout, short. Staminate catkins erect, 6–10 in. long. Nuts usually 3 in each bur. Rich soil, especially N. Rarely found on soils containing much lime.*

2. C. pumila Mill. CHINQUAPIN. A small tree or shrub. Leaves oblong, acute or obtuse at both ends, serrate with divergent teeth, dark green and smooth above, white-woolly below. Nuts solitary, nearly globular. Common southward in rich woods.*

III. QUERCUS L.

Trees or shrubs with entire, serrate, or lobed leaves, which are often persistent. Staminate flowers in slender catkins, each subtended by quickly deciduous bracts, and consisting of 3–12 stamens inclosed by a 4–8-parted perianth, often containing an abortive ovary. Pistillate flowers solitary or in small clusters, each consisting of a 3-celled ovary with 2 ovules in each cell, though rarely more than 1 ovule matures; styles short, erect, or recurved. Pistillate flowers surrounded by a scaly involucre which at maturity becomes a cup inclosing the base of the fruit or sometimes a large part of it. Fruit an ovoid or subglobose, 1-seeded, thin-shelled nut (acorn).

A. Fruit annual; leaves not bristle-tipped, though often mucronate.

1. Q. alba L. White Oak. A large tree with light gray bark. Leaves obovate-oblong, 3–9-lobed, lobes rounded and mostly entire, bright green above, paler below, short-petioled. Cup hemispherical, scales rough, woolly when young, but becoming smooth with age; acorn oblong-ovate, about 1 in. long. Common in damp soil. Wood strong and durable; one of the most valuable timber trees.*

2. Q. stellata Wang. Post Oak. A tree of medium size with rough gray bark. Leaves broadly obovate, deeply lyrate-pinnatifid into 5–7 rounded, divergent lobes, upper lobes much the longer, smooth above, yellowish-downy beneath; petioles about 1 in. long. Cup hemispherical, nearly sessile; acorn ovoid, 2–3 times as long as the cup. On dry soil. Wood hard and valuable.

3. Q. lyrata Walt. Swamp Oak. A large tree with gray or reddish bark. Leaves obovate-oblong, deeply pinnatifid, lobes narrow, often toothed, thin, smooth above, white, densely woolly beneath. Cup round-ovate, scales cuspidate, inclosing nearly the whole of the depressed-globose acorn. On wet soil. Wood strong and very durable.*

4. Q. macrocarpa Michx. Bur Oak. A medium-sized to very large tree, with roughish gray bark. Leaves obovate or oblong, lyrately and deeply sinuate-lobed, smooth above, pale and downy beneath. Cup very deep and thick, abundantly fringed about the margin, ¾–2 in. in diameter. Acorn, half or more (sometimes entirely) inclosed by the cup. Reaches its full size only on rich bottom lands S. and W., where it becomes one of the finest timber oaks. Wood very hard and heavy.

5. Q. Muhlenbergii Engelm. YELLOW CHESTNUT OAK. A tree of medium or large size with gray bark. Leaves oblong or oblanceolate, usually acute at the apex and obtuse or rounded at the base, coarsely and evenly toothed; veins straight, impressed above and prominent beneath; petioles slender. Cup hemispherical, sessile or short-peduncled, with flat scales, $\frac{1}{2}$ in. broad, inclosing about half the ovoid acorn, which is $\frac{2}{3}$–$\frac{3}{4}$ in. long. Common on dry soil. Wood close-grained, durable, and valuable.

6. Q. Prinus L. SWAMP CHESTNUT OAK. A large tree with brown, ridged bark. Leaves oblong or oblong-lanceolate, rather obtuse, crenately toothed, minutely downy beneath; petioles slender, about 1 in. long. Cup hemispherical, peduncles longer than the petioles, scales acute, tubercular, appressed; acorn oblong, acute, 1 in. or less in length, edible. Common on low ground. Wood strong and valuable.*

7. Q. virginiana Mill. LIVE OAK. A large tree with rough gray or brown bark and a low, spreading top. Leaves leathery, evergreen, oblong or oblanceolate, often somewhat 3-lobed on young trees, margin rolled under, dark green and shining above, pale below; petioles short, stout. Fruit often in short racemes, cup top-shaped, scales closely appressed, hoary, peduncles $\frac{1}{2}$–1 in. long; acorn from subglobose to oblong, the longer form occurring on the younger trees. On low ground near the coast. Wood very hard and durable; valued for shipbuilding.*

B. Fruit biennial; leaves entire or with bristle-pointed lobes.

8. Q. rubra L. RED OAK. A large tree. Leaves oval or obovate, green above, pale and slightly downy beneath; sinuses shallow and rounded, lobes 8–12, taper-pointed; petioles long. Cups saucer-shaped, with fine scales; acorn ovate or oblong, about 1 in. long. Common; wood not valuable; leaves turning red after frost and often remaining on the tree through the winter.

9. Q. velutina Lam. BLACK OAK. A large tree with rough, dark brown outer bark and thick, bright yellow inner bark. Leaves broadly oval, usually cut more than halfway to the midrib, sinuses rounded; lobes about 7, sharply toothed at the apex, smooth above, usually downy on the veins beneath; cup hemispherical or top-shaped, with coarse scales, short-peduncled, inclosing about half the roundish acorn. Common; wood not valuable, but the inner bark used for tanning and dyeing.*

10. Q. falcata Michx. SPANISH OAK. A small or medium-sized tree with leaves 3–5-lobed at the apex, obtuse or rounded at the base, grayish-downy beneath, lobes lanceolate and often scythe-shaped,

sparingly cut-toothed. Cup top-shaped, with coarse scales, inclosing about half the nearly round acorn. Common in dry woods. Foliage quite variable in outline and lobing; bark valuable for tanning.*

11. Q. nigra L. Black-Jack Oak. A small tree; leaves obovate, usually with three rounded lobes at the apex, the lobes bristle-pointed, rounded, or slightly cordate at the base, rusty-pubescent beneath, shining above, coriaceous, short-petioled; cup top-shaped, short-peduncled, with coarse and truncate scales, inclosing about one third of the oblong-ovate acorn. An almost worthless tree, its presence indicating a thin and sterile soil.*

12. Q. phellos L. Willow Oak. A tree of medium size, leaves lanceolate or elliptical, scurfy when young and becoming smooth with age, very short-petioled; cup shallow, sessile; acorn subglobose. Wet soil. Often planted for shade.*

19. ULMACEÆ. Elm Family

Trees or shrubs with watery juice; alternate, simple, petiolate, serrate, stipulate leaves, which are usually 2-ranked; and small, bisexual, or somewhat monœcious, apetalous flowers. Calyx of 3–9 sepals, which are distinct or partly united; stamens as many as the sepals and opposite them. Ovary 1–2-celled; styles 2, spreading. Fruit a key, nut, or drupe.*

I. ULMUS L.

Trees with straight-veined, unsymmetrical, doubly serrate leaves; stipules early deciduous. Flowers bisexual; calyx bell-shaped, 4–9-cleft. Stamens slender, protruding. Ovary compressed; styles 2, spreading. Fruit membranaceous, flat, winged on the edge.*

1. U. fulva Michx. Slippery Elm. A tree of medium size, with rough, downy twigs, and rusty, densely woolly bud scales. Leaves large, thick, very rough above, downy beneath, ovate or obovate, taper-pointed at the apex, unsymmetrical, obtuse or somewhat cordate at the base, coarsely and doubly serrate; calyx lobes and pedicels downy. Fruit broadly oval, downy over the seed, the wing smooth. Inner bark very fragrant when dried, and a popular domestic remedy.*

2. U. campestris L. English Elm. A large tree, with short, rather upright or ascending branches. Leaves not bilaterally symmetrical, oval, acute or sometimes a little taper-pointed, doubly

serrate, 3–4 in. long. Flowers in close clusters with very short pedicels. Fruit obovate-elliptical, with a fissure extending almost to the seed, nearly smooth and not ciliate. Considerably planted as a shade tree and rarely escaped from cultivation. Very variable, one variety with thick ridges of cork on the twigs.

3. U. americana L. White Elm. A large tree with gray bark, drooping branches, and smooth or slightly downy twigs. Leaves oval or obovate, abruptly taper-pointed at the apex, obtuse and oblique at the base, slightly rough above, soft-downy or soon smooth beneath. Flowers in close fascicles; pedicels slender, smooth. Fruit oval or obovate, with 2 sharp teeth bending toward each other at the apex;

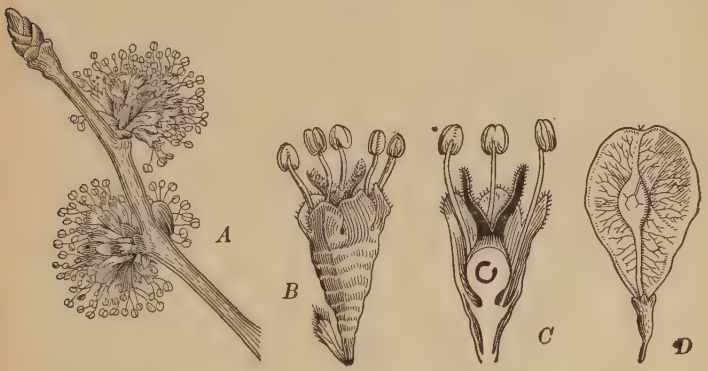


Fig. 12. *Ulmus campestris*

A, a flowering twig; *B*, a flower; *C*, longitudinal section of a flower; *D*, a fruit. (*A*, *D*, natural size; *B*, *C*, enlarged.) (After Wossidlo)

wing reticulate-veined, downy on the margin. In moist, rich soil. A widely planted ornamental tree; wood strong but warping badly, and not durable when exposed.*

4. U. racemosa Thomas. Cork Elm, Rock Elm. A large tree 80–100 ft. high, with the young twigs somewhat downy; the branches often with ridges of cork. Leaves much as in *U. americana*, but smaller and less sharply serrate. Flowers racemed, on thread-like pedicels. Fruit oval, downy on the surface and densely ciliate. In rich soil, especially along river banks. A highly valuable timber tree.

5. U. alata Michx. Winged Elm. A small tree with branches corky-winged. Leaves small, ovate-lanceolate, acute, sharply serrate, base nearly equal-sided, rough above, downy beneath, nearly sessile.

Flowers in small clusters. Fruit oblong, downy on the sides, ciliate on the edges. On rich soil. Occasionally producing a second set of flowers and fruit from September to November.*

II. CELTIS L.

Trees or shrubs with entire or serrate, petioled leaves. Flowers greenish, axillary, on wood of the same season, the staminate in small clusters, the fertile single or 2–3 together.*

1. C. occidentalis L. Hackberry. A large or medium-sized tree, having much the appearance of an elm, bark dark and rough. Leaves ovate, taper-pointed at the apex, abruptly obtuse and inequilateral at the base, sharply serrate, often 3-nerved from the base, smooth above, usually somewhat downy below. Fruit a small, dark-purple drupe. On rich soil.

2. C. mississippiensis Bosc. Southern Hackberry. A tree usually smaller than the preceding, bark gray, often very warty. Leaves broadly lanceolate or ovate, long taper-pointed at the apex, obtuse or sometimes heart-shaped at the base, entire or with very few serratures, smooth on both sides, 3-nerved. Fruit a purplish-black, globose drupe.*

20. MORACEÆ. Mulberry Family

Trees, shrubs, or herbs, usually with milky juice, alternate leaves, large deciduous stipules, and small monœcious or diœcious flowers crowded in spikes, heads, or racemes, or inclosed in a fleshy receptacle. Staminate flowers with a usually 4-lobed calyx, and with as many stamens opposite the lobes; filaments usually inflexed in the bud, straightening at maturity. Pistillate flowers usually 4-sepalous; ovary 1–2-celled, 1–2-ovuled; styles 2; receptacle and perianth often fleshy at maturity.*

I. MORUS L.

Trees or shrubs with milky juice, rounded leaves, and monœcious flowers in axillary spikes. Staminate flowers with a 4-parted perianth, and 4 stamens inflexed in the bud. Pistillate flowers with a 4-parted perianth, which becomes fleshy in the multiple fruit, the pulpy part of which consists of the

thickened calyxes of many flowers; ovary sessile; stigmas 2, linear, spreading; the fleshy perianth inclosing the ovary at maturity.*

1. M. rubra L. Red Mulberry. A small tree. Leaves cordate-ovate, often 3–5-lobed on vigorous shoots, taper-pointed at the apex, serrate, rough above, white, densely woolly beneath. Mature fruiting spikes oblong, drooping, dark red or purple, edible. On rich soil. Wood very durable, bearing exposure to the weather.

2. M. alba L. White Mulberry. A small tree. Leaves ovate, heart-shaped, acute at the apex, rounded and often oblique at the base, serrate or sometimes lobed. Smooth and shining on both sides. Mature fruit light red or white. Introduced and common about old dwellings.*

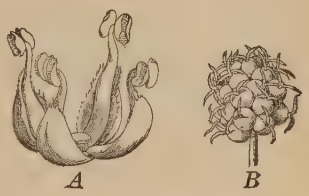


Fig. 13. *Morus alba*

A, staminate flower, about four times natural size; *B*, cluster of pistillate flowers. (After Warming)

II. MACLURA Nutt. (TOXYLON)

A small tree with milky juice. Leaves alternate, petioled, spines axillary. Flowers dicœcious. Staminate flowers in short axillary racemes; calyx 4-parted; stamens 4, inflexed in the bud. Pistillate flowers in axillary, peduncled, capitate clusters; calyx 4-parted; ovary sessile; style long; calyxes becoming thickened and fleshy in fruit and aggregated into a large, dense, globular head.*

1. M. pomifera Schneider. Osage Orange. A small tree with ridged, yellowish-brown bark. Leaves minutely downy when young, becoming smooth and shining with age, ovate or ovate-oblong, taper-pointed at the apex, obtuse or subcordate at the base, entire, petioled. Staminate racemes about 1 in. long. Pistillate flower clusters about 1 in. in diameter. Fruit yellowish, tubercled, 3–4 in. in diameter. In rich soil. Native in Texas and extensively planted for hedges. Wood very durable when exposed to the weather, and therefore used for fence posts. As the wood does not swell or shrink with changes in its moisture, it is highly valued for wheel hubs, etc.*

III. BROUSSONETIA L'Her.

Small trees with milky juice. Leaves alternate, petioled. Flowers dicœcious; staminate in cylindrical spikes, with a

4-cleft calyx, 4 stamens, and a rudimentary ovary; pistillate flowers in capitate clusters, calyx 3–4-toothed. Ovary stalked; style 2-cleft. Fruit in a globular head.*

1. **B. papyrifera** Vent. Paper Mulberry. A round-topped tree with yellowish-brown bark. Leaves cordate, often irregularly 2–3-lobed, serrate, rough above, downy beneath, long-petioled. Staminate spikelets peduncled, 2–3 in. long. Pistillate heads stout, peduncled, about 1 in. in diameter. Introduced from Asia and very common S. about old dooryards.*

IV. CANNABIS L.

Coarse herbs with very tough, fibrous bark. Leaves usually opposite, palmately compound. Flowers small, dicœcious, greenish, the staminate ones in compound racemes or panicles, the pistillate ones in spikes. Calyx of the staminate flowers of 5 sepals, that of the pistillate flowers of 1 large sepal which covers the ovary and the akene.

1. **C. sativa** L. Common Hemp. An erect plant, 4–8 ft. high. Leaves large, petioled, of 5–7 lanceolate, irregularly serrate or toothed leaflets. Cultivated from Europe, S. and W., for its fiber, and sometimes runs wild along roadsides in rich soil.

21. URTICACEÆ. Nettle Family

Herbs with watery juice, stem and leaves often clothed with stinging hairs. Leaves undivided, stipulate. Flowers small, greenish, unisexual, apetalous in axillary clusters. Calyx of the staminate flowers 4–5-parted or 4–5-sepalous; stamens as many as the sepals and opposite them; filaments inflexed in the bud and straightening at maturity; anthers 2-celled. Calyx of pistillate flowers 2–4-sepalous; ovary sessile, 1-celled; stigma simple or tufted. Fruit an akene commonly inclosed in the dry, persistent calyx.*

URTICA L.

Annual or perennial herbs. Leaves with stinging hairs, opposite, petioled, several-nerved, dentate or incised, stipulate. Flowers monœcious or dicœcious. Calyx of the staminate

flowers 4-parted; stamens 4, inserted around a rudimentary ovary. Pistillate flowers with 4 unequal sepals, the inner ones dilated in fruit; akenes smooth, compressed.*

1. U. gracilis Ait. SLENDER NETTLE. Perennial, slender, with some stinging hairs, 2–6 ft. high. Leaves ovate-lanceolate or narrower, with slender petioles, taper-pointed, sharply serrate, with 3–5-nerves arising from the rounded or sometimes almost heart-shaped base, almost smooth; stipules lanceolate. Flower clusters in branching panicled spikes, longer than the petioles. Flowers dicœcious or bisexual.

2. U. urens L. SMALL NETTLE. Annual; stem stout, 4-angled, hairy, 12–18 in. tall, with few stinging hairs; branches slender. Leaves elliptical or ovate, serrate or incised, 3–5-nerved, acute or obtuse at the ends, thin, hairy; petioles often as long as the blades; stipules short. Flower clusters axillary, in pairs, loose, mostly shorter than the petioles. On damp soil in waste places. Naturalized from Europe.

22. SANTALACEÆ. SANDALWOOD FAMILY

Herbs, shrubs, or trees with entire leaves. Flowers usually small. Calyx 4–5-cleft, its limb epigynous. Corolla wanting. Stamens as many as the calyx lobes and opposite them, inserted on the margin of a fleshy disk. Style 1; ovary 1-celled, with 2–4 ovules borne at the top of a free central placenta. Fruit 1-seeded.

COMANDRA Nutt.

Low, smooth perennials with herbaceous stems, rather woody below, often parasitic. Leaves alternate and nearly sessile. Flowers nearly white, in small umbel-like clusters, bisexual. Calyx bell-shaped at first. Stamens borne on a 5-lobed disk which surrounds the pistil; anthers connected by a tuft of hairs to the calyx lobes.

1. C. umbellata Nutt. BASTARD TOADFLAX. Plant 8–10 in. high, with very leafy stems. Roots attached to the roots of trees, from which they draw nourishment. Leaves oblong or oblanceolate, pale, nearly 1 in. long. Umbel-like clusters about 3-flowered, longer than the leaves. Rocky, dry woods.

23. LORANTHACEÆ. Mistletoe Family

Parasitic shrubs or herbs, leaves opposite, leathery, without stipules. Flowers monœcious or diœcious, clustered or solitary; perianth of both calyx and corolla, or of a calyx only, or sometimes wanting, the limb epigynous; sepals 2–8. Stamens as many as the sepals, and opposite them. Ovary 1-celled; ovule 1. Fruit a berry.*

PHORADENDRON Nutt.

Evergreen, shrubby plants, parasitic on trees; branches greenish, jointed, and very brittle. Leaves leathery. Flowers diœcious, in short jointed spikes. Staminate flowers globular, calyx 2–4-lobed, stamens sessile at the base of the lobes, anthers transversely 2-celled. Stigma sessile. Berry 1-seeded.*

1. **P. flavescens** Nutt. American Mistletoe. Very round, bushy; branches very brittle at the joints, opposite or whorled, 6 in. to 2 ft. long. Leaves flat, leathery, or somewhat fleshy, nearly veinless, obovate, entire, with short petioles. Flowering spikes solitary or 2–3 together in the axils of the leaves. Berry roundish, white, glutinous. Parasitic on many deciduous trees.*

24. ARISTOLOCHIACEÆ. Dutchman's Pipe Family

Herbaceous plants, apparently stemless or with twining and leafy stems. Leaves alternate, without stipules, petioled, mostly roundish or kidney-shaped. Flowers axillary, solitary or clustered, bisexual. Calyx tubular, 3- or 6-lobed, usually colored. Petals none. Stamens 6–12, epigynous. Pistil 1; ovary mostly 6-celled, many-seeded.*

I. ASARUM L.

Perennial, apparently stemless, aromatic herbs, with slender, branching rootstocks. Leaves long-petioled, from kidney-shaped to halberd-shaped. Flowers axillary, peduncled. Calyx actinomorphic, 3-lobed, withering-persistent. Stamens 12, the filaments partially united with the style and usually prolonged beyond the anthers. Ovary 6-celled, with parietal placentæ, many-seeded. Mature capsule roundish, often somewhat fleshy.*

1. A. canadense L. WILD GINGER. Plant soft-hairy. Leaves 2, large, kidney-shaped, on long petioles, with the flower borne on a short peduncle between them. Flower greenish outside, brownish-purple inside. Calyx lobes epigynous, taper-pointed, widely spreading, relaxed at the tip. Rich, shady woods, common N.

2. A. virginicum L. VIRGINIA ASARUM. Leaves evergreen, 1–3 to each plant, smooth, mottled, round-cordate, entire, 2–3 in. long and broad; petioles smooth or downy along one side, 3–7 in. long. Flowers nearly sessile, greenish without, dull purple within, $\frac{2}{3}$–$\frac{3}{4}$ in. long; tube inflated below, narrow at the throat, lobes spreading. Rich, shady woods.*

II. ARISTOLOCHIA L.

Erect or twining perennial herbs or woody vines. Leaves alternate, heart-shaped at the base, palmately nerved, petioled, entire. Flowers zygomorphic, solitary, or in small clusters. Calyx perigynous or epigynous, tubular, irregular. Stamens mostly 6, sessile, apparently united to the angled and fleshy 3–6-lobed or -angled stigma. Capsule naked, 6-valved; seeds very numerous.*

1. A. macrophylla Lam. DUTCHMAN'S PIPE, PIPE VINE. A tall climber. Leaves dark green, smooth, round-kidney-shaped, sometimes 1 ft. wide. Peduncles 1-flowered, with a single clasping bract. Calyx 1½ in. long, bent into the shape of a pipe, its border abruptly spreading, brownish-purple. Rich woods, often cultivated.

2. A. tomentosa Sims. DUTCHMAN'S PIPE. Stem woody, climbing high, branches and leaves densely woolly. Leaves heart-shaped, prominently veined, 3–5 in. long and broad. Flowers axillary, mostly solitary, on slender peduncles. Calyx bent in the shape of a pipe, yellowish-green with a dark purple throat, limb unequally 3-lobed, rugose, reflexed. Anthers in pairs below the 3 spreading lobes of the stigma. Capsule oblong. Stems sometimes 30 ft. long. Rich woods S.*

25. POLYGONACEÆ. BUCKWHEAT FAMILY

Herbs with alternate, entire leaves, and usually with sheathing stipules above the swollen joints of the stem. Flowers apetalous, generally bisexual, with a 3–6-cleft calyx, generally colored and persistent. Fruit a compressed or 3-angled akene, inclosed in the calyx; seeds with endosperm, which does not generally inclose the embryo. Stamens 4–12, on the base of the calyx.

I. RUMEX L.

Coarse herbs, many of them troublesome weeds. Flowers small, usually green or greenish, generally in whorls borne in panicled racemes. Calyx of 6 nearly distinct sepals, the 3 inner ones larger and more petal-like than the 3 outer, and one or more of them usually with a little knob or tubercle on its back. Stamens 6; styles 3; stigmas short, fringed. Fruit a 3-angled akene, closely covered by the 3 inner calyx lobes, enlarged and known as valves.

1. **R. crispus** L. YELLOW DOCK. Stout, smooth, 3–4 ft. high. Leaves lanceolate, margins very wavy, acute, the lower more or less heart-shaped. Root long, tapering gradually downward, yellow, very tough. Flowers in whorls crowded in long, straight, slender racemes. Valves roundish-heart-shaped, mostly tubercled. A very hardy weed, naturalized from Europe.

2. **R. verticillatus** L. SWAMP DOCK. Perennial. Stem stout, smooth, erect or ascending, 3–5 ft. tall. Lower leaves oblong, obtuse at the apex and usually heart-shaped at the base, long-petioled, often 12–18 in. long; upper leaves narrower and often acute at both ends. Flowers bisexual or somewhat monœcious, in dense whorls; pedicels slender, $\frac{1}{2}$–$\frac{2}{3}$ in. long, tapering downward, reflexed at maturity. Calyx green, the valves broadly triangular, abruptly pointed, reticulated, a distinct long and narrow tubercle on the back of each. Swamps and wet ground.*

3. **R. Acetosella** L. SHEEP SORREL. Perennial herbs with slender creeping and bud-bearing roots. Stem simple or branched, smooth. Leaves petioled, narrowly halberd-shaped, usually widest above the middle, the apex acute or obtuse; upper stem leaves often nearly linear and not lobed. Flowers dicœcious, small, in terminal, naked, panicled, interrupted racemes. Calyx greenish; the pistillate panicles becoming reddish. Fruit less than $\frac{1}{12}$ in. long, granular, longer than the calyx. A common weed, naturalized from Europe, in dry fields and on sour soils. Foliage very acid.*

II. POLYGONUM L.

Annual or perennial, terrestrial or aquatic herbs, with enlarged joints and simple, alternate, entire leaves; the sheathing stipules often cut or fringed. Flowers bisexual, usually white or rose-colored, each flower or cluster subtended by a membranaceous bract similar to the stipules of the leaves.

Calyx mostly 5-parted, the divisions petal-like, erect and persistent. Stamens 3–9; styles 2–3-parted. Fruit lens-shaped or 3-angled.*

1. P. aviculare L. KNOTGRASS. Annual or perennial. Stem prostrate or ascending, diffuse, smooth, 6–24 in. long. Leaves small, lanceolate or linear-oblong, obtuse, nearly or quite sessile. Sheaths thin and dry, 2–3-cleft or cut. Flower clusters axillary, 1–5-flowered; flowers inconspicuous, nearly sessile. Calyx greenish-white, 5-parted, the lobes with white or colored borders. Stamens 5–8; style 3-parted. Akene 3-angled, not shining. A common weed in dooryards and where the ground is trampled.*

2. P. lapathifolium L. Annual. Stem branching, 1–4 ft. high. Leaves lanceolate or broader, wedge-shaped at the base and tapering from near the base to an extremely slender point, ciliate, varying greatly in length. Sheaths not ciliate or fringed. Spikes oblong to linear, closely flowered, erect or nearly so, $\frac{1}{2}$–2 in. long. Calyx white or pink. Stamens 6; style 2-cleft. Akene ovate, lens-shaped, $\frac{1}{12}$ in. wide or less. In wet soil.

3. P. acre HBK. WATER SMARTWEED. Perennial. Smooth or nearly so; stems erect or ascending, rooting below, 2–5 ft. high. Leaves lanceolate or broader, tapering at both ends, petioled, ciliate, translucent-dotted, acrid, $1\frac{1}{2}$–8 in. long. Sheaths cylindrical, falling early, bristly-fringed. Spikes erect or nearly so, loosely flowered, $\frac{3}{4}$–3 in. long. Calyx whitish-greenish or flesh color. Stamens 8; style usually 3-parted. Akene oblong, lens-shaped, smooth and shining. Swamps and wet soil, especially S.

4. P. Persicaria L. LADY'S THUMB. Annual. Smooth or nearly so. Stem erect or ascending, 6–24 in. high. Leaves lanceolate or narrower, tapering at both ends, usually with a dark triangular or crescent-shaped spot near the center, very variable in length. Sheaths more or less bristle-fringed. Spikes ovoid or oblong, dense, erect, peduncled, $\frac{3}{8}$–2 in. long. Calyx pink or purple. Stamens usually 6; styles 2–3-cleft more than half their length. Akene broadly ovate and lens-shaped, often somewhat triangular, smooth and shining. In waste ground, often a troublesome weed. Naturalized from Europe.

5. P. hydropiperoides Michx. MILD WATER PEPPER. Perennial. Stem smooth, slender, erect, decumbent, or prostrate, 1–3 ft. long. Leaves usually narrowly lanceolate, but variable, acute, ciliate, 2–6 in. long. Sheaths wrinkled, bristle-fringed. Spikes erect, slender, often with the flowers scattered, $\frac{1}{2}$–$2\frac{1}{2}$ in. long. Calyx pale pink, greenish or nearly white. Stamens 8; style 3-parted more than half its length. Akene 3-angled, smooth and shining. In swamps and wet places, especially S.

6. P. dumetorum L. False Buckwheat. Perennial. Stems slender, twining, branched, 2–10 ft. long. Leaves ovate, taper-pointed, heart-shaped to halberd-shaped at the base, long-petioled. Stipules cylindrical, truncate. Flowers in axillary, more or less compound and leafy racemes. Calyx greenish-white, the outer lobes winged and forming a margin on the pedicel. Stamens 8. Stigmas 3. Akene 3-angled, black, smooth, and shining. Margins of fields and thickets.*

III. FAGOPYRUM Hill

Smooth annual herbs, with more or less triangular leaves; the sheathing stipules cylindrical or funnel-shaped. Flowers bisexual, white, greenish or tinged with rose color, in terminal or axillary, often panicled, racemes. Calyx petal-like (Fig. 14), 5-parted. Stamens 8. Styles 3, with knobbed stigmas. Akene 3-angled, much longer than the persistent calyx (Fig. 14).

Fig. 14. Buckwheat (*Fagopyrum esculentum*)

A, flower; *B*, section of flower; *C*, fruit. (All somewhat magnified.) (After Marchand)

1. F. esculentum Mœnch. Buckwheat. Annual, nearly smooth. Leaves halberd-shaped, 1–3 in. long. Flowers white or nearly so, with 8 yellow nectar-bearing glands between the stamens. Old fields and thickets, escaped from cultivation. Introduced from Europe or western Asia.

26. CHENOPODIACEÆ. Goosefoot Family

Herbs or shrubs. Leaves simple, alternate, without stipules. Flowers small, actinomorphic, either bisexual or more or less monœcious or diœcious. Calyx free from the ovary. Corolla wanting. Stamens usually 5, opposite the sepals. Styles or stigmas generally 2. Fruit with 1 seed, usually inclosed in a small, bladdery sac, sometimes an akene.

I. SPINACIA L.

Herbs. Flowers dicœcious, in close axillary clusters. Staminate flowers 3–5-sepaled, with 4 or 5 projecting stamens; pistillate flowers with a tubular 2-toothed or 4-toothed calyx.

1. S. oleracea Mill. SPINACH. A soft annual or biennial herb. Leaves triangular, ovate, or halberd-shaped, petioled. Cultivated from Asia as a pot herb.

II. CHENOPODIUM L.

Annual or perennial herbs. Stems erect or spreading. Leaves alternate, usually white-mealy. Flowers small, greenish, in panicled spikes. Calyx 3–5-parted, the lobes often slightly fleshy and keeled. Stamens 5; filaments thread-shaped. Styles 2–3, distinct or united at the base. Seed lens-shaped.*

1. C. Botrys L. JERUSALEM OAK. A low, spreading plant, covered with sticky down. Leaves with slender petioles, oblong, sinuately

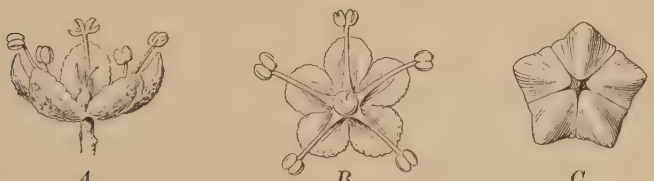


FIG. 15. Pigweed (*Chenopodium album*)

A, *B*, flower; *C*, fruit. (All about seven times natural size)

lobed or the lobes pinnate. Flowers in loose, diverging, leafless racemes. The whole plant is sweet-scented. Introduced from Europe and naturalized in gardens and along roadsides.

2. C. glaucum L. OAK-LEAVED GOOSEFOOT. Annual, succulent, somewhat mealy. Stem spreading, much branched, 5–12 in. high. Leaves varying from oblong to lanceolate, obtuse, some or all of them more or less sinuate-toothed, 1–2 in. long. Flower clusters mostly small axillary spikes. A common weed. Naturalized from Europe.

3. C. album L. LAMB'S QUARTERS. COMMON PIGWEED. Annual, somewhat mealy. Stem erect, usually branching, 1–4 ft. high. Leaves

varying from rhombic-ovate to (the uppermost) nearly linear, narrowed at the base, acute, somewhat angulate-toothed, 1–4 in. long. Spikes terminal and in the leaf axils, often panicled. Calyx with keeled lobes, in fruit nearly covering the smooth seed. A common and troublesome weed. Naturalized from Europe.

4. **C. urbicum** L. Upright Goosefoot. Annual, little or not at all mealy. Stem stout, erect, and with erect branches, 1–3 ft. high. Leaves halberd-shaped or triangular, acute, coarsely and sharply toothed, except the upper ones, the larger ones 3–6 in. long. Spikes in a narrow, erect panicle. Lobes of the calyx not keeled. Waste ground. Naturalized from Europe.

27. AMARANTHACEÆ. Amaranth Family

Mostly herbs, with nearly the characters of the *Chenopodiaceæ*, but with usually 3 dry, translucent, persistent, often colored, bracts beneath the flower. Most of the genera are tropical; our commonest species are troublesome weeds, usually flowering in midsummer or later.

AMARANTHUS L.

Mostly annual herbs. Leaves alternate, simple, thin, usually entire, often bristle-tipped. Flowers mostly 3-bracted, small, green or purplish in our wild species, in axillary clusters or dense terminal spikes. Calyx of 5 or sometimes 3 distinct erect sepals. Stamens distinct, usually 5, anthers 2-celled. Styles or stigmas 2 or 3. Fruit small, bladdery, 1-seeded, with 2 or 3 beaks formed by the withered styles.

1. **A. graecizans** L. Tumbleweed. Smooth, pale green. Stem diffusely branched, whitish, the branches slender, ascending. Leaves small, varying from obovate to spatulate, obtuse or retuse, $\frac{3}{8}$–$1\frac{1}{2}$ in. long. Flowers greenish, in small axillary clusters, covered by stiff, sharp-pointed bracts. Sepals 3. In waste ground and a common field and garden weed. In the autumn the leaves drop and the globular stem and branches roll freely about before the wind.

2. **A. spinosus** L. Spiny Amaranth. Stem stout, ridged, smooth, bushy-branched, often red, 1–4 ft. high. Leaves varying from ovate to lanceolate, tapering to both ends, dull green, $\frac{3}{4}$–3 in. long, each with a pair of stiff spines in its axil. Flower clusters of two sorts,

the upper ones of staminate flowers in long slender spikes, the axillary ones globular, composed of pistillate flowers. Bracts lance-awl-

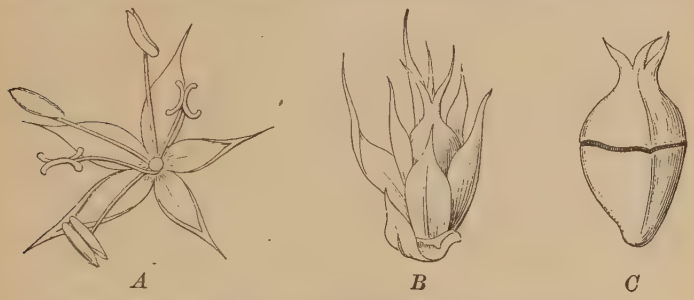


FIG. 16. Prince's feather (*Amaranthus hypochondriacus*)

A, staminate flower; *B*, pistillate flower; *C*, fruit. (All magnified.) (After Schnizlein)

shaped about the length of the 5 sepals. In waste ground, fields, and gardens. Naturalized from tropical America.

A. retroflexus L. and **A. hybridus** L., usually known as pigweed, are common autumn-flowering weeds.

28. PHYTOLACCACEÆ. POKEWEED FAMILY

Plants with alternate entire leaves. Flowers bisexual, 5-parted, with the characters of the Goosefoot Family, but the ovary generally consisting of several carpels, which unite to form a berry.

PHYTOLACCA L.

Perennial herbs. Stems tall, branching. Leaves large, entire. Flowers small, in terminal racemes, pedicels bracted. Calyx of 4–5 nearly equal, persistent sepals. Stamens 5–15, inserted at the base of the calyx. Styles 5–12, recurved at the apex. Fruit a depressed-globose, juicy berry.*

1. P. decandra L. POKEWEED. Stems erect, smooth, branched above, usually dark purple, 4–7 ft. tall; root large, fleshy, poisonous. Leaves ovate-lanceolate, smooth, acute, long-petioled. Racemes peduncled, many-flowered, opposite the leaves; flowers white, becoming purplish. Stamens 10, shorter than the sepals. Styles 10, carpels 10.

Fruit a dark purple berry. A weed on waste ground. The young branches are often eaten like asparagus, and the root, known as "garget root," is used in medicine.*

29. AIZOACEÆ. Ice Plant Family

Mostly fleshy plants, mainly natives of Africa. Flowers often large and showy. Stamens often doubled and some of them petal-like. Ovary 2–many-celled.

[Our only very common genus belongs to a subfamily which has little resemblance to the fleshy "ice plants," found in some gardens, which best represent the family as a whole.]

MOLLUGO L.

Low branching annuals. Sepals 5, greenish outside, white inside. Corolla wanting. Stamens 5, alternate with the sepals, or 3, alternate with the cells of the ovary. Capsule 3-celled, many-seeded.

1. **M. verticillata** L. Carpet Weed. Stems branching and forming radiating patches. Leaves clustered in apparent whorls at the joints of the stem, spatulate. Flowers in little sessile umbels at the joints. Stamens commonly 3. A troublesome weed in sandy soil and common on sandy beaches and river banks.

30. PORTULACACEÆ. Purslane Family

Generally herbs. Leaves opposite or alternate, entire; stipules dry and membranaceous. Sepals 2. Petals 4 or more, distinct or united below. Stamens 4 or more, hypogynous or perigynous. Ovary usually superior, 1-celled; style simple or 3-cleft; ovules 2–many. Capsule opening transversely with a lid, or 2–3-valved.

I. CLAYTONIA L.

Perennial. Stem simple, smooth, erect, 4–10 in. high. Leaves 2, opposite, smooth, succulent. Flowers in a terminal raceme. Sepals 2, ovate, persistent. Petals 5, sometimes joined at the base. Stamens 5, somewhat perigynous. Style 3-cleft; ovary 1-celled, 3–6-seeded.

1. C. virginica L. Spring Beauty. Stem simple, erect from a deep, tuberous root. The 2 stem leaves narrowly elliptical, 3–6 in. long, smooth, fleshy; basal leaves occasionally produced. Flowers on short pedicels. Petals white or pink, with darker veins, $\frac{1}{4}$–$\frac{3}{8}$ in. long, notched. Capsules shorter than the persistent sepals. Common in rich woods.*

2. C. caroliniana Michx. Northern Spring Beauty. Flowers fewer, smaller, and whiter than in No. 1, fragrant. Leaves 1–2 in. long, ovate-lanceolate or spatulate, rather distinctly petioled. Moist woods, especially N.

II. PORTULACA L.

Annual. Stems low, diffuse, and spreading, fleshy. Leaves entire, mostly alternate. Flowers terminal, perigynous. Sepals 2, united at the base. Petals usually 5, quickly withering. Stamens 8–20. Style 3–8-parted. Capsules globose, opening by the upper portion coming off like a lid, 1-celled, many-seeded.*

1. P. oleracea L. Purslane. Stems prostrate, diffuse, fleshy. Leaves alternate, flat, obovate or wedge-shaped. Flowers solitary, sessile, opening in bright sunshine in the morning and usually withering before noon. Sepals broad, acute. Petals yellow. Stamens 10–12. Capsule very many-seeded, seeds small, wrinkled. A common garden weed.*

2. P. grandiflora Hook. Garden Portulaca. Stems fleshy, erect or ascending, densely hairy or nearly smooth, 3–6 in. long. Leaves alternate, cylindrical, fleshy, $\frac{1}{2}$–1 in. long. Flowers 1–2 in. wide, white, yellow, or red, showy, opening only in sunlight. Common in cultivation and often growing spontaneously.*

31. CARYOPHYLLACEÆ. Pink Family

Herbs sometimes woody below, with thickened nodes. Leaves opposite, entire; stipules small and dry or none. Sepals 4–5. Petals 4–5 (rarely 0), usually hypogynous. Stamens usually 8–10, hypogynous or perigynous. Styles 2–5 (rarely 1). Ovules 1–many. Fruit usually a capsule.

A

Sepals distinct or nearly so. Petals (if any) without claws. Capsules several–many-seeded.

Styles usually 3. Capsule ovoid. — Stellaria, I

Styles 5 or 4. Capsule cylindrical. — Cerastium, II

B

Sepals more or less united. Petals with claws. Capsule several–many-seeded.

(*a*) Calyx without bracts, its lobes long and leaf-like. Agrostemma, III

(*b*) Calyx without bracts, lobes not leaf-like. Styles 3 or 4. Silene, V

(*c*) Calyx without bracts, lobes not leaf-like. Styles 5 (rarely 4). Lychnis, IV

(*d*) Calyx with little bracts at the base. Styles 2. Dianthus, VI

I. STELLARIA L. (ALSINE)

Slender, usually smooth herbs. Flowers small, white, solitary, or in forking cymes. Sepals 5 (rarely 4). Petals 5 (rarely 4), 2-cleft or -divided. Stamens 10 (rarely 8, 5, or 3), maturing in 2 sets. Styles 3 (rarely 4 or 5), opposite the same number of petals; ovary 1-celled, many-ovuled. Capsule short, splitting into as many valves as there are styles.

1. S. longifolia Muhl. Long-Leaved Stitchwort. Stem slender, usually erect, 8–18 in. high, often sharply 4-angled. Leaves linear or nearly so, spreading. Flower clusters peduncled, many-flowered, the pedicels spreading. Petals 2-parted, at length longer than the calyx. Perennial in meadows and grassy thickets, especially N.

2. S. graminea L. Smooth, weak, ascending. Stem sharply 4-angled, 12–20 in. long. Leaves linear-lanceolate or broader, widest a little above the base, ciliate, acute, $\frac{3}{4}$–$1\frac{1}{4}$ in. long. Cyme loose, with slender, widely spreading pedicels. Flowers $\frac{1}{4}$–$\frac{3}{4}$ in. in diameter. Sepals and petals about equal in length, the petals cleft almost to the base. Seeds with many minute tubercles. Fields and roadsides, often among grass. Naturalized from Europe.

3. S. media Cyrill. Common Chickweed. Stem prostrate, 6–18 in. long, with a line or two of hairs along it. Leaves ovate, taper-pointed, the lower petioled, the upper sessile. Petals shorter than the sepals, sometimes wanting. An annual weed, naturalized from Europe, common in damp, shady places N.

II. CERASTIUM L.

Annual or perennial. Stems diffuse, usually downy; leaves opposite. Flowers white, peduncled, in terminal, regularly

forking cymes. Sepals 4–5. Petals 4–5, notched or 2-cleft. Stamens 10. Styles 5 or less. Capsules cylindrical, 1-celled, many-seeded.*

1. C. arvense L. Field Chickweed. Perennial. Stems tufted, erect or ascending, 4–10 in. high. Basal leaves and those of flowerless branches linear-oblong, crowded; those of flowering stems linear or lance-linear. Flowers $\frac{1}{2}$–$\frac{3}{4}$ in. in diameter, in cymes. Petals obcordate, much longer than the sepals. Pods hardly longer than the calyx. In dry or rocky soil.

2. C. vulgatum L. Mouse-Ear Chickweed. Annual or sometimes perennial. Stems diffuse, tufted, clammy-downy, 6–12 in. high. Lower leaves spatulate, the upper oblong, acute, or obtuse; bracts thin and dry. Flowers in loose cymes, pedicels becoming much longer than the calyx. Sepals lanceolate, acute, about as long as the 2-cleft petals. Slender capsule becoming twice as long as the calyx and curved upward. A common garden weed.*

3. C. brachypodum Robinson. Annual. Stems 3–10 in. high, clammy-downy. Lower leaves oblanceolate or spatulate, the upper ones linear to lanceolate. Pedicels shorter or not much longer than the calyx. Petals longer than the sepals. Capsule straight or slightly curved upwards. In dry soil.

III. AGROSTEMMA L.

Annual. Stem pubescent, branching above. Leaves linear-lanceolate or linear, pubescent, sessile. Flowers showy, on long and naked peduncles in terminal corymbs. Calyx tubular, the tube oblong, 10-ribbed; lobes elongated, leaf-like, deciduous. Petals 5, shorter than the calyx lobes, entire. Stamens 10. Styles 5, capsules 1-celled.*

1. A. Githago L. Corn Cockle. Stem erect, rather slender, 1–3 ft. tall, gray, with long, appressed hairs. Leaves linear-lanceolate, acuminate, erect, 2–4 in. long. Petals obovate, notched, purple. Capsule 5-toothed, many-seeded; seeds black. An introduced weed, common in grain fields.*

IV. LYCHNIS L.

Plants with nearly the same characteristics as *Silene*, but usually with 5 styles.

1. L. Coronaria Desr. Mullein Pink. A forking perennial plant, 2 ft. high, covered with white, cottony down. Leaves very wavy,

spatulate; stem leaves ovate-lanceolate, wavy, clasping. Peduncles long, 1-flowered. Flowers about $1\frac{1}{4}$ in. broad, deep crimson. Calyx tube very strongly 5-ribbed, with 5 smaller ones between; calyx teeth short and slender. Petals somewhat notched. Cultivated in old gardens; from Europe.

2. L. chalcedonica L. Scarlet Lychnis, London Pride. A tall, hairy perennial (about 2 ft.). Leaves lance-ovate, somewhat clasping. Flower cluster flat-topped and very dense. Flowers bright scarlet, not very large. Petals 2-lobed. Common in old gardens; from Japan.

3. L. Drummondii Wats. Perennial, erect, glandular-downy and sticky, 1–3 ft. high. Leaves oblanceolate or linear, acute, $\frac{3}{4}$–3 in. long. Flowers few, on slender pedicels, white or purplish, $\frac{3}{8}$–$\frac{3}{4}$ in. long. Petals not much longer than the tubular calyx. Capsule $\frac{1}{2}$–$\frac{2}{3}$ in. long. Seeds with little tubercles. In dry soil W.

V. SILENE L.

Annual or perennial herbs. Stems erect or decumbent and diffuse. Leaves often connate or whorled. Flowers clustered or solitary, usually pink or white. Calyx tubular, more or less inflated, 5-toothed, 10-nerved, bractless. Petals 5, long-clawed, and with the ten stamens inserted at the base of the ovary. Styles 3; ovary 1-celled or 3-celled at the base, opening by 6 teeth, many-seeded. Seeds usually roughened.*

1. S. antirrhina L. Sleepy Catchfly. Stem smooth, slender, 8–30 in. high, sticky in spots. Leaves lanceolate or linear. Flowers rather few and small, panicled. Calyx ovoid. Petals inversely heart-shaped, pink, opening only for a short time in sunshine. Dry waste ground.

2. S. Armeria L. Catchfly, None-so-Pretty. A smooth, erect annual or biennial, 6–15 in. high. Several nodes of the stem are usually covered for part of their length with a sticky substance. Leaves very smooth, with a bloom beneath, lanceolate or oblong-lanceolate, clasping. Flowers showy, dark pink, nearly $\frac{1}{2}$ in. in diameter, in flat-topped clusters. Calyx club-shaped. Petals somewhat notched. Cultivated from Europe and introduced.

3. S. noctiflora L. Night-Flowering Catchfly. A tall, coarse annual or biennial weed, covered with sticky hairs. Lower leaves spatulate, upper ones lanceolate, pointed. Flowers large, white, opening at night or in cloudy weather. Calyx teeth long, awl-shaped. Petals 2-parted. In fields and gardens. Naturalized from Europe.

4. S. pennsylvanica Michx. Wild Pink. A perennial with low, clustered stems (4–8 in.). Basal leaves wedge-shaped or spatulate, those of the stem lanceolate. Flowers medium-sized, clustered. Petals wedge-shaped, notched, pink, with a crown at the throat of the corolla. Gravelly soil E.

5. S. virginica L. Fire Pink. A slender perennial, with erect stem, 1–2 ft. high. Basal leaves spatulate, the upper leaves oblong-lanceolate. Flowers few, peduncled, large and showy, bright crimson. Corolla crowned, petals deeply 2-cleft. Woods.

6. S. latifolia Britten and Rendle. Snappers, Rattlebox. A perennial branched herb about 1 ft. high. Leaves opposite, smooth, ovate or ovate-lanceolate. Calyx thin and bladdery, beautifully veined. Petals white, 2-cleft. Capsule nearly globular. In fields and along roadsides, especially eastward. Naturalized from Europe.

VI. DIANTHUS L.

Tufted, mostly perennial herbs, often shrubby at the base. Leaves narrow and grass-like. Flowers solitary or variously clustered. Calyx tubular, 5-toothed, with overlapping bracts at the base. Petals 5, with long claws. Stamens 10, maturing 5 at a time. Styles 2; ovary 1-celled. Capsule cylindrical, 4-valved at the top.

1. D. barbatus L. Sweet William. Perennial, often in large clumps. Stems erect, branching above, smooth, 1–2 ft. tall. Leaves lanceolate, 2–3 in. long, acute. Flowers crimson-pink, white or variegated, in terminal clusters; bracts linear, as long as the calyx. Common about old gardens; from Europe.*

2. D. Armeria L. Deptford Pink. Rather erect, annual, with stiff stems 1–2 ft. high. Leaves very dark green, linear, 1–2 in. long, the lower obtuse, the upper acute. Flowers loosely clustered, small, dark pink. Calyx tube $\frac{1}{2}$–$\frac{3}{4}$ in. long, nearly cylindrical. Petals narrow, speckled with very small whitish dots. In sandy fields eastward. Introduced from Europe; sometimes cultivated.

3. D. plumarius L. Common Pink, Grass Pink. Leaves grass-like, with a whitish bloom. Petals white, pink, or variegated, with the limb fringed. Flowers solitary, fragrant. Hardy perennials, cultivated from Europe.

4. D. Caryophyllus L. Carnation, Clove Pink. Much like the preceding species, but with larger fragrant flowers; the broad petals merely crenate. Hothouse perennials (some hardy varieties), cultivated from Europe.

32. NYMPHÆACEÆ. Water Lily Family

Perennial aquatic herbs. Leaves usually floating, often shield-shaped. Flowers borne on naked scapes. Floral envelopes and stamens all hypogynous or epigynous. Sepals 3–6. Petals 3–5 or often very numerous. Stamens many. Carpels 3 or more, free or united. Fruit a berry or a group of separate carpels.

I. NYMPHÆA L.

Rootstock horizontal, thick, cylindrical. Leaves heart-shaped, floating or erect. Flowers yellow. Sepals 4–6, green on the outside, obovate, concave. Petals many, hypogynous, the inner ones becoming small and stamen-like. Stamens many, hypogynous. Ovary cylindrical, many-celled; stigma disk-shaped. Fruit ovoid.*

1. N. advena Ait. Yellow Pond Lily, Cow Lily, Spatter-Dock. Leaves oval or orbicular, rather thick, often downy beneath. Flowers bright yellow, 2–3 in. in diameter, depressed-globular. Sepals 6. Petals thick and fleshy, truncate. Stamens in several rows; anthers nearly as long as the filaments. In slow streams and still water.*

II. CASTALIA Salisb.

Rootstock horizontal, creeping extensively. Leaves floating, entire, shield-shaped or heart-shaped. Flowers showy. Sepals 4, green without, white within. Petals many, white, becoming smaller towards the center. Stamens many, the outer with broad and the inner with linear filaments. Ovary many-celled, stigmas shield-shaped and radiating. Fruit berry-like, many-seeded.*

1. C. odorata Woodville and Wood. White Water Lily. Rootstock large, branched but little. Leaves floating, entire, the notch narrow and basal lobes acute, green and smooth above, purple and downy beneath. Petioles and peduncles slender. Flowers white, very fragrant, opening in the morning, 3–5 in. broad. Fruit globose; seeds inclosed in a membranaceous sac. In ponds and still water.*

2. C. tuberosa Greene. Much like No. 1. Rootstock bearing loosely attached, often compound tubers. Leaves round-kidney-shaped, seldom purple beneath. Flowers larger than in No. 1, scentless or nearly so. Slow streams, especially W.

III. NELUMBO Adans.

Rootstock large and stout. Leaves round, shield-shaped, often raised above the water. Flowers large, raised above water at first, but often submerged after blooming. Sepals and petals hypogynous, numerous, the inner sepals and outer petals not distinguishable from each other. Stamens many, hypogynous. Pistils several, 1-ovuled, borne in pits in the flattish upper surface of a top-shaped receptacle, which enlarges greatly in fruit.

1. **N. lutea** Pers. American Lotus, Water Chinquapin. Rootstock often 3–4 in. in diameter, horizontal. Leaves 1½–2½ ft. broad, prominently ribbed, with much bloom above, often downy beneath. Petioles and peduncles stout. Flowers pale yellow, 5–9 in. broad. Sepals and petals falling quickly. Fruit top-shaped, 3–4 in. in diameter; the seeds ½ in. in diameter. In ponds and slow-running streams W., introduced from the Southwest.*

33. RANUNCULACEÆ. Buttercup Family

Herbs, rarely shrubs, usually with biting or bitter juice. Leaves basal or alternate (in *Clematis* opposite; stem leaves or involucre whorled in *Anemone*); stipules none or adnate to the petiole. Floral organs all distinct and unconnected. Sepals 5 or more (rarely 2–4), falling early, often petal-like. Petals none, or 5 or more (rarely 3). Stamens many. Carpels many, 1-celled; stigmas simple; ovules 1 or more. Fruit composed of 1-seeded akenes or many-seeded follicles. Seeds small.

A

Flowers zygomorphic.

With a spur. — Delphinium, XII

With a hood. — Aconitum, XIII

B

Flowers actinomorphic.

1. Petals present (in (*c*) not very unlike the stamens).
   - (*a*) Petals very large and showy. — Pæonia, IX
   - (*b*) Petals small, tubular at the tip. — Coptis, X
   - (*c*) Petals narrow, spatulate, on slender claws. — Actæa, XIV
   - (*d*) Petals prolonged backward into spurs. — Aquilegia, XI
   - (*e*) Petals flat, with a little scale at the base, inside. — Ranunculus, I

2. Petals none, or very small and stamen-like.

(*a*) Sepals yellow. Caltha, VIII

(*b*) Sepals greenish or white, falling as the flower opens. Thalictrum, II

(*c*) Sepals white or colored, involucre sepal-like. Hepatica, IV

(*d*) Sepals 4. Plants climbing. Clematis, VI

(*e*) Sepals 5, white. Flowers axillary and terminal. Pods 2–several-seeded. Isopyrum, VII

(*f*) Sepals white or colored. Plants not climbing. Akenes more or less tailed with the styles in fruit. Anemone, V

(*g*) Sepals 5–10, white. Flowers in an umbel. Roots tuberous. Anemonella, III

I. RANUNCULUS L.

Annual or perennial herbs. Leaves alternate, usually deeply lobed or parted. Flowers axillary or in corymbs, white or yellow. Sepals 3–5. Petals 3–5, flat, with a small pit or scale inside at the narrowed base. Stamens usually numerous. Pistils few or several in a head. Akenes flattened, pointed.*

1. R. pusillus Poir. Low Spearwort. Perennial. Stems several, erect or ascending, branched, smooth, 6–15 in. high. Leaves entire or slightly toothed, the lower round or cordate, long-petioled, the upper lanceolate or elliptical, nearly or quite sessile. Flowers very small, about $\frac{1}{10}$ in. wide, yellow. Petals 1–5, as long as the sepals. Stamens 3–10. Akenes smooth, with a very short point. On muddy banks.*

2. R. abortivus L. Small-Flowered Crowfoot. Perennial. Stems smooth, branching, 12–18 in. high. Basal leaves round-cordate, crenate, petioled. Stem leaves 3–5-parted, with wedge-shaped or linear divisions, sessile. Flowers very small, pale yellow. Sepals reflexed, longer than the petals. Akenes in a globose head, smooth, without a beak. Common on wet ground and waste places.*

3. R. recurvatus Poir. Hooked Crowfoot. Perennial. Stem erect, hairy, 1–2 ft. high. Leaves all nearly alike, petioled, 3–5-lobed, with the lobes wedge-shaped, cut or toothed at the apex. Flowers small, pale yellow. Petals minute, shorter than the reflexed sepals. Akenes in a globular head, smooth, with a slender, recurved beak. On low ground.*

4. R. fascicularis Muhl. Tufted Buttercup. Perennial. Stems clustered from thickened fibrous roots, ascending, 5–9 in. high, covered with close-lying silky hairs. Leaves 3–5-divided, the divisions

lobed and cleft into oblong or linear divisions. Flowers about 1 in. in diameter. Petals 5–7, yellow, spatulate-oblong or obovate. Akenes hardly margined, beak slender, straight or slightly curved. On hillsides or in woods or prairies.

5. R. septentrionalis Poir. MARSH BUTTERCUP. Stems smooth or slightly hairy, erect, or in wet ground often forming long runners. Leaves 3-divided, on long petioles, the divisions stalked, cleft or lobed, and wedge-shaped. Petals yellow, obovate, twice as long as the sepals. Akenes flat, strongly margined, beak stout and nearly straight. In moist soil.

6. R. hispidus Michx. RECLINING BUTTERCUP. Perennial. Stems ascending or spreading, densely soft-hairy when young, few-leaved. Leaves pinnately 3–5-divided, with sharply cleft divisions. Flowers ½–1½ in. in diameter. Petals about twice as long as the spreading sepals. Head of fruit globose or nearly so. Akenes broadly oval, lens-shaped, with a narrow margin. In dry woods and thickets.

7. R. pennsylvanicus L. f. UPRIGHT BUTTERCUP. Perennial. Stems rough-hairy, erect, 2–3 ft. high. Leaves compound in threes, on long and very hairy petioles; leaflets long-stalked, 3-parted, the divisions sharply lobed or toothed. Flowers small. Petals yellow, shorter than the sepals. Akenes flat, smooth, in oblong heads; beak broad and straight. On low ground.*

8. R. bulbosus L. BULBOUS BUTTERCUP, EARLY BUTTERCUP. Stem upright, from a solid bulb about as large as a filbert, about 1 ft. high, hairy. Basal leaves 3-divided, the divisions lobed and cleft. Peduncles furrowed. Flowers large and showy (½–1 in. in diameter). Sepals strongly reflexed. Petals roundish, wedge-shaped at the base. Akenes with a very short beak. Naturalized from Europe. Common in grass fields in New England.

9. R. acris L. TALL BUTTERCUP. Erect, hairy, 2–3 ft. high. Leaves 3–7-parted, the divisions of the lower ones wedge-shaped, deeply cut and lobed. Peduncles not furrowed. Sepals spreading, downy. Petals obovate, a little smaller and paler yellow than in No. 8. A common weed, naturalized from Europe, in grass fields and elsewhere, especially eastward.

II. THALICTRUM L.

Erect perennial herbs. Leaves compound, with stipules. Flowers in panicles or racemes, often somewhat monœcious or diœcious, wind-fertilized. Sepals 4–5, petal-like. Petals none. Stamens many. Carpels few or many; ovule 1. Fruit a small head of akenes. [The following species are both usually diœcious.]

1. T. dioicum L. Early Meadow Rue. Plant 1–2 ft. high, smooth and pale or with a bloom. Leaves all petioled, most of them thrice compound in threes; leaflets thin and delicate, roundish, 3–7-lobed. Flowers in slender panicles, purplish or greenish; staminate ones with slender, thread-like filaments, from which hang the conspicuous yellowish anthers. Rocky woods and hillsides.

2. T. polygamum Muhl. Tall Meadow Rue. Stems from fibrous roots, tall and coarse, nearly or quite smooth, 4–8 ft. tall. Leaves twice compound, those of the stem sessile, the others long-petioled; leaflets oval or oblong, often cordate, smooth or downy beneath, quite variable in size on the same plant. Flowers small, in large panicles. Sepals 4 or 5, white. Filaments club-shaped. Akenes short-stalked. Thickets and meadows E.

III. ANEMONELLA Spach. (SYNDESMON)

Small, perennial herbs. Leaves compound, smooth, the basal ones long-petioled, those of the stem sessile. Flowers in a terminal umbel, slender-pediceled. Sepals petal-like. Petals none. Pistils 4–15; stigmas sessile, truncate.*

1. A. thalictroides Spach. Rue Anemone. Stem slender, 6–10 in. high, from a cluster of tuberous roots. Basal leaves long-petioled, twice compound in threes; leaflets oval, heart-shaped, 3–5-lobed. Stem leaves 2–3 compound in threes, whorled, the long-stalked leaflets veiny, forming an involucre of 6–9 apparently simple leaves. Flowers 3–6 in an umbel, $\frac{1}{2}$–$\frac{3}{4}$ in. wide; sepals 6–10, white. In rich woods.*

IV. HEPATICA Hill

Involucre of 3 small, simple leaves, so close to the flower as to look like a calyx. Leaves all basal, 3-lobed, heart-shaped, thick, and evergreen, purplish-red beneath. Flowers single, on rather slender hairy scapes.

1. H. triloba Chaix. Round-Lobed Hepatica. Lobes of the leaves obtuse or rounded; those of the involucre obtuse; sepals 6–12, varying from blue to white.

2. H. acutiloba DC. Sharp-Lobed Hepatica. Closely similar to the former, except for the acute lobes of the leaves and tips of the involucre.

[Both species have many local names, such as Liverleaf, Liverwort, Noble Liverwort, Spring Beauty.]

V. ANEMONE L.

Perennial herbs, usually with basal leaves, and 2 or 3 opposite or whorled stem leaves, constituting an involucre some distance below the flower or flower cluster. Sepals few or numerous, colored and petal-like. Petals usually wanting. Akenes pointed, or with long, feathery tails.

1. A. patens L., var. **Wolfgangiana.** PASQUE FLOWER. Low plants, 1 in.–1 ft. high, clothed with long, silky hairs. Leaves divided in threes. Flower single, large, showy, pale-purplish, borne on a peduncle developed before the leaves. Carpels many, with long, hairy styles, which in fruit form tails 2 in. long. Prairies and bluffs, N.W.

2. A. caroliniana Walt. CAROLINA ANEMONE. Stem simple, from a roundish tuber, slightly downy, 6–12 in. high, bearing a single flower about 1 in. broad. Basal leaves 2–3, long-petioled, compound in threes, the divisions cut or lobed; stem leaves sessile, compound in threes, the divisions wedge-shaped. Sepals 12–20, white; head of fruit becoming oblong; akenes woolly. In open woods W.*

3. A. cylindrica Gray. LONG-FRUITED ANEMONE. Plants about 2 ft. high, branching, with an involucre of long-petioled, divided, and cleft leaves, from within which spring several long, naked peduncles. Flowers greenish-white. Sepals obtuse. Head of fruit cylindrical, composed of very many densely woolly akenes. Dry woods and prairies.

4. A. virginiana L. Plant hairy, 2–3 ft. high. Peduncles 6–12 in. long, sometimes forking, the first ones naked, the later ones with a little 2-leaved involucre at the middle. Leaves of the involucre 3, each 3-parted, the divisions ovate-lanceolate, pointed. Sepals acute. Head of fruit ovoid. Woods and meadows.

5. A. canadensis L. Plant hairy, rather low. Peduncle arising from a 3-leaved primary involucre, then branching, each branch bearing at the middle a 2-leaved secondary involucre. Leaves of the primary involucre broadly wedge-shaped, 3-cleft, the divisions cut and toothed. Sepals obovate, white. Head of fruit spherical. In low ground or woods.

6. A. quinquefolia L. WIND FLOWER, WOOD ANEMONE. Stem simple, from a thread-like rootstock; involucre of 3 leaves, each petioled, and of 3 leaflets, which are cut, toothed, or parted. Peduncle 1-flowered. Sepals 4–7, white, often tinged with purple outside. Carpels 15 or 20. This species is very nearly related to, but now regarded as distinct from, the European *A. nemorosa.*

VI. CLEMATIS L.

Perennial herbs or slightly woody vines, usually climbing by the leafstalks. Leaves opposite, simple or compound. Sepals 4, petal-like. Petals very small or wanting. Pistils numerous, tipped by the persistent styles, which often become long and plumose in fruit.*

1. C. crispa L. Marsh Clematis. Stem climbing, a little woody below, slightly downy above, 3–5 ft. high. Leaves pinnately compound; leaflets 5–7, varying from lanceolate to ovate, thin, entire or 3–5-lobed. Flowers showy, perfect, solitary, on long axillary peduncles. Sepals lanceolate, taper-pointed, thick, wavy on the margins, twice the length of the stamens, light bluish-purple, 1–1½ in. in length. Tails of the ripened akenes 1 in. long, silky. Rich woods and river banks S.*

2. C. Viorna L. Leather Flower. Stem climbing, nearly smooth, 6–10 ft. long. Leaves usually pinnately compound, the lowest pair often compound in threes and the upper pair simple. Leaflets usually 5–7, oblong-ovate or oval, acute, firm, entire or lobed. Calyx bell-shaped, nodding; sepals ovate, taper-pointed with a short, recurved point, thick and leathery, reddish-purple, 1 in. long. Tails of the akenes plumose, 1½ in. long, brownish. On river banks and rich soil.*

VII. ISOPYRUM L.

Small, smooth herbs. Leaves 2–3 times compound, in threes; the leaflets 2–3-lobed. Flowers peduncled, white. Sepals 5, petal-like, soon falling. Petals wanting (in our species). Stamens 10–40. Pistils 3–6 or more.

1. I. biternatum T. & G. A delicate, erect plant, with alternate branches, looking much like *Anemonella*, with clustered stems from perennial tuberous roots. Damp woods.

VIII. CALTHA L.

Smooth perennials with large, roundish leaves. Sepals petal-like, 5–9. Petals none. Pistils 5–10, each consisting of a 1-celled ovary with a nearly sessile stigma. Fruit a many-seeded follicle.

1. C. palustris L. Marsh Marigold, Cowslips, Meadow Buttercup (both the latter unsuitable names, but in common use). Stem hollow, smooth, ascending; leaves smooth, roundish and heart-shaped,

or kidney-shaped, with crenate, dentate, or nearly entire margins; the broad oval sepals bright yellow. Swamps or wet ground.

IX. PÆONIA L.

Perennial, from thick, fleshy roots; stems shrubby or herbaceous. Leaves much divided. Flowers terminal, large and showy. Sepals 5, leaf-like and persistent. Petals 5 or more. Pistils 3–5; ovaries surrounded by a disk.*

1. P. officinalis L. Garden Peony. Herbaceous; flowering stems 1–2 ft. high. Leaves ample; leaflets lance-ovate, cut or incised, smooth. Flowers double, white or red. Follicles 2, erect, many-seeded. Common in gardens.*

X. COPTIS Salisb.

Low, smooth perennials, with 3-divided basal leaves. Flowers small, white, on scapes. Sepals 5–7, petal-like, soon falling. Petals 5–7, small, club-shaped, tubular at the apex. Stamens 15–25. Pistils 3–7, stalked. Pods thin and dry, 4–8-seeded.

1. C. trifolia Salisb. Gold Thread. A pretty, delicate plant, with slender, 1-flowered scapes, from long, bright-yellow, thread-like rootstocks, which are bitter and somewhat medicinal. Leaves later than the flowers, each of 3 wedge-shaped leaflets, which finally become shining and evergeen. Damp, cold woods and bogs.

XI. AQUILEGIA L.

Perennials, with leaves twice or thrice palmately compound, the divisions in threes.

Sepals 5, petal-like, all similar. Petals 5, all similar, each consisting of an expanded portion, prolonged backward into a hollow spur, the whole much longer than the calyx. Pistils 5, forming many-seeded pods.

1. A. canadensis L. Wild Columbine. Flowers scarlet without, yellow within, nodding; spurs rather long.

2. A. vulgaris L. Garden Columbine. Flowers often double, and white, blue, or purple. Spurs shorter and more hooked. Cultivated from Europe, and sometimes become wild.

XII. DELPHINIUM L.

Annual or perennial herbs. Stem erect, simple or branched. Leaves alternate, petioled, palmately divided. Flowers in

terminal racemes or panicles, showy. Sepals 5, colored, irregular, the upper one prolonged into a spur. Petals 4, unequal, the two upper ones with long spurs which are inclosed in the spur of the upper sepal, the other two short-stalked. Pistils 1–5; ovaries many-seeded.*

1. **D. tricorne** Michx. Dwarf Larkspur. Perennial. Stem simple, from a tuberous root, usually low (½–1 ft. high), but sometimes 2 ft. high. Leaves deeply 5-parted, the divisions irregularly 3–5-cleft. Racemes few-flowered, loose. Flowers blue, sometimes white. Pods diverging. Southward.

2. **D. azureum** Michx. Blue Larkspur. Perennial. Stem usually simple, slender, downy, 1–2 ft. high. Leaves 2–3 in. wide, 3–5-parted, the divisions cleft into 3–5 narrow, toothed, or entire lobes. Flowers in a strict, many-flowered, terminal raceme, showy, blue or whitish. Spur ascending, curved; lower petals bearded, 2-cleft. Pods erect. On rich or rocky soil in open places, N.*

XIII. ACONITUM L.

Erect, perennial herbs. Leaves alternate, palmately lobed or cut. Flowers irregular, in panicles or racemes. Sepals 5, the back one large, arched, and hooded, the front one the narrower. Petals 2–5, small, the 2 back ones clawed and covered by the hood of the sepals; 3 lateral ones small or wanting. Follicles 3–5. Seeds many, wrinkled.

1. **A. Napellus** L. Monkshood. An erect, poisonous plant, 1–2 ft. high. Raceme simple and densely flowered. Flowers dark blue. Cultivated from Europe.

Several native species of *Aconitum* occur within our limits, but they are not common.

XIV. ACTÆA L.

Perennial. Stem simple. Leaves 2–3, compound in threes; leaflets ovate, sharply cut or toothed. Flowers white, in a short and thick terminal raceme. Sepals 4–5, soon deciduous. Petals 4–10, small. Pistil single; stigma 2-lobed. Fruit a many-seeded berry.*

1. **A. rubra** Willd. Red Baneberry. Stem about 2 ft. high. Raceme ovoid or hemispherical. Petals acute. Pedicels slender. Berries usually red, sometimes white, ovoid. Common N.

2. A. alba Miller. BANEBERRY. Stem erect, smooth or nearly so, 18–24 in. high. Leaves large and spreading; leaflets thin. Racemes very broad. Petals slender, truncate. Pedicels red, thickened in fruiting; berries white. In rich woods, more common S.*

34. BERBERIDACEÆ. BARBERRY FAMILY

Herbs or shrubs. Leaves alternate, simple or compound, usually without stipules. Sepals petal-like. Petals hypogynous, distinct, their number some multiple of 2, 3, or 4, never of 5. Stamens usually one opposite each petal; anthers commonly opening by 2 uplifted lids (the stamens of *Podophyllum* are exceptional). Pistil 1, 1-celled; ovules 2 or more. Fruit a berry or capsule.

I. PODOPHYLLUM L.

Perennial. Stem simple, smooth, erect, 12–15 in. tall, bearing 2 leaves with a large white flower between them. Sepals 6, falling off as the flower opens. Petals 6–9, obovate. Stamens twice as many as the petals; anthers splitting open lengthwise. Pistil 1; stigma large, flat, sessile. Fruit berry-like, 1-celled, many-seeded.*

1. P. peltatum L. MAY APPLE. Rootstock rather large. Leaves orbicular, shield-shaped, 5–9-lobed and toothed, smooth, 9–12 in. wide. Flowers 1–2 in. wide, on a peduncle 1–2 in. long. Stamens prominent; anthers opening longitudinally. Fruit 1½–2 in. long, oval, fragrant, edible; each seed surrounded by a pulpy covering. In rich woods. The roots and leaves are used in medicine.*

II. CAULOPHYLLUM Michx.

A perennial, smooth herb, 1–2½ ft. high. Leaf large, single, sessile, thrice compound in threes, borne high up on the stem; there is also a large, very compound basal leaf. Flowers racemed or panicled, yellowish-green. Sepals 6, with 3 bractlets. Petals 6, gland-like, somewhat curved inward at the tip, much smaller than the sepals. Pistil 2-ovuled, the ovary soon bursting open and leaving the 2 blue seeds to ripen naked.

1. C. thalictroides Michx. BLUE COHOSH, PAPPOOSE ROOT. Whole plant purplish and covered with a bloom when young. Flowers appearing before the leaf is fully developed. Rich woods.

III. BERBERIS L.

Spiny shrubs with yellow wood. Leaves spinous-toothed, jointed on the very short petiole, often reduced to 3–7-cleft spines. Flowers in racemes, solitary or in pairs. Sepals 8–9, the outer minute. Petals 6, each with 2 nectar glands at the base. Stamens 6. Ovules few. Berry 1–2-seeded ; seeds bony-coated.

1. B. vulgaris L. Common Barberry. A shrub 4–6 ft. high. Leaves obovate, spinous-serrate; those on the old shoots mere spines. Flowers pale yellow, in drooping racemes. Stamens irritable, closing quickly toward the center of the flower when touched. Berry ½ in. long, nearly ellipsoidal in shape, scarlet or orange-scarlet, very acid, eatable when cooked. Cultivated from Europe and introduced in eastern New England and locally in the upper Mississippi Valley.

2. B. Thunbergii DC. A low shrub. Leaves entire, turning red and remaining so for a considerable time in autumn. Flowers solitary or in pairs. Berries bright red, remaining on the branches all winter. Cultivated from Japan.

35. MAGNOLIACEÆ. Magnolia Family

Trees or shrubs. Leaves alternate, not toothed or serrate. Flowers solitary, large and showy. Floral envelopes and stamens hypogynous. Calyx and corolla colored alike, the parts of the perianth forming 3 or more circles of 3 parts each. Stamens many. Carpels many, usually joined over the long receptacle and forming a sort of cone-shaped fruit, which may be either fleshy or dry.

I. MAGNOLIA L.

Aromatic trees or shrubs. Leaves alternate, often in clusters at the ends of the branches, entire, usually thick and leathery ; stipules large, quickly deciduous. Flowers terminal, showy, bisexual. Sepals 3, caducous. Petals 6–12, in 2–4 rows, concave. Stamens numerous. Ovaries numerous, 1-celled, 2-seeded, the mature follicles opening at the beak and the fleshy seeds remaining for some time suspended by slender threads.*

1. M. virginiana L. Sweet Bay. A small tree with light gray bark. Leaves scattered on the branches, evergreen, thick and leathery, oval or oblong, smooth and green above, white and with

a bloom, downy beneath, 4–6 in. long. Flowers white, fragrant, 2–3 in. in diameter; petals 9, concave. Cone 1½–2 in. long, pink. Common in swamps and along streams, New York and southward (a few in eastern Massachusetts). The leaves often used in flavoring soups, etc.

2. M. acuminata L. CUCUMBER TREE. A tree 60–90 ft. high. Leaves thin, oblong or oval, acute, light green and somewhat downy beneath, 5–10 in. long. Flowers oblong-bell-shaped, greenish-yellow, 2 in. long. Petals much longer than the sepals. Cone of fruit 2–3 in. long, often curved, cylindrical. Woods, especially S.

3. M. macrophylla Michx. LARGE-LEAVED UMBRELLA TREE. A small tree with gray bark. Leaves clustered at the ends of the branches, oblong or obovate, obtuse at the apex, cordate at the base, green and glabrous above, white and downy beneath, 1½–3 ft. long; petioles stout. Flowers white with a purple center, fragrant, 8–12 in. wide. Petals oblong, obtuse, two or three times as long as the sepals. Cone ovate, 4–6 in. long, bright red at maturity. Shady woods on light soil S.*

4. M. Fraseri Walt. EAR-LEAVED UMBRELLA TREE. A small tree with a slender trunk and widely spreading branches. Leaves clustered at the ends of the branches, deciduous, oblong or obovate, contracted, cordate and eared at the base, smooth on both sides, 8–12 in. long; petioles slender. Flowers white and fragrant, 6 in. broad. Petals longer than the sepals, spatulate or oblong, obtuse at the apex, narrowed at the base. Cone 3–4 in. long, pink at maturity. In rich woods S.*

II. LIRIODENDRON L.

A large tree with rough, dark-colored bark. Leaves scattered on the branches, deciduous, 3-lobed, truncate, stipuled, petioled. Flowers bisexual. Sepals 3, reflexed. Petals 6, erect. Stamens numerous. Ovaries numerous, 2-ovuled, joined over each other on the elongated receptacle, never opening, deciduous.*

1. L. tulipifera L. TULIP TREE. The largest tree in the family. Leaves roundish in outline, mostly 3-lobed, the terminal lobe truncate or broadly notched, usually heart-shaped at the base, smooth, green above, lighter beneath; petioles slender. Flowers terminal, bell-shaped, greenish-yellow marked with orange. Petals obovate, obtuse, about as long as the sepals. Mature cones ovate, acute, 2–3 in. long. Common on low ground, Pennsylvania and S. Often called "white wood," or, incorrectly, "white poplar." Wood valuable for making boxes and light furniture.*

36. CALYCANTHACEÆ. Calycanthus Family

Shrubs. Leaves opposite, entire, without stipules. Flowers solitary, often sweet-scented. Sepals and petals numerous, the outer sepals bract-like. Stamens many, short, the inner ones usually sterile. Ovaries several, inserted on the inside of an irregular, hollow, pear-shaped receptacle something like a large rose hip, forming 1-seeded akenes in fruit.

CALYCANTHUS L. (BUTNERIA)

Shrubs, 4–8 ft. tall; branches opposite. Leaves oval, downy beneath, short-petioled; both leaves and bark aromatic. Sepals and petals many, in several rows, somewhat fleshy, indistinguishable. Pistils several, inserted on the inner side of the persistent calyx tube. Mature fruit pear-shaped, dry, inclosing the akenes.*

1. C. floridus L. Sweet-Scented Shrub, Strawberry Bush, Spice Bush, Shrub. A widespreading bush, 4–8 ft. high; twigs downy. Leaves oval or oblong, acute or taper-pointed, rough above, downy beneath, 2–3 in. long. Flowers 1 in. wide, brownish-purple, very fragrant. Sepals united below to form a cup, on the inside of which the other parts of the flower are inserted; cup leafy-bracted on the outside. Banks of streams and rich hillsides S., often cultivated.*

37. ANNONACEÆ. Papaw Family

Trees or shrubs. Leaves alternate, entire, pinnately veined. Flowers bisexual, hypogynous, axillary, solitary. Calyx of 3 sepals; corolla of 6 thickish petals in 2 rows. Stamens many; filaments very short. Pistils several or many, becoming fleshy or pulpy in fruit.

ASIMINA Adans.

Shrubs or small trees. Leaves deciduous. Flowers nodding. Sepals 3, ovate. Petals 6, the 3 outer ones larger and spreading. Stamens very numerous, crowded on the globular receptacle. Ovaries 3–15, sessile, 1-celled, several-ovuled. Fruit a large, fleshy, oblong berry; seeds large, horizontal.*

1. A. triloba Dunal. PAPAW. A small tree, 10–20 ft. high; bark nearly smooth, lead-colored. Leaves oblong-obovate, acute at the apex, obtuse at the base, rusty-downy when young and becoming smoother with age, 6–10 in. long. Flowers on branches of the previous season, appearing before or with the leaves; the short peduncles and the sepals brown-downy; petals purple, obovate, 3–4 times longer than the sepals. Fruit 3–5 in. long, edible when ripe. Common on banks of streams, especially S. and S.W. The bark is very tough and is often used in the place of rope.*

38. LAURACEÆ. LAUREL FAMILY

Aromatic plants, nearly always trees or shrubs. Leaves alternate, simple, usually entire, and marked with translucent dots. Calyx regular, hypogynous, of 4 or 6 colored sepals. Stamens in 3 or 4 circles of 3 each, the anthers opening by valves. Style single. Fruit a 1-seeded berry or drupe.

I. SASSAFRAS Nees.

A tree with rough, yellowish bark and a spreading top. Leaves deciduous, entire or 2–3-lobed. Flowers dicœcious, involucrate, at the end of the twigs of the previous season. Calyx 6-parted, persistent in the pistillate flowers. Stamens 9, in 3 rows. Pistillate flowers with 4–6 abortive stamens and a single ovary. Fruit a drupe.*

1. S. variifolium Ktze. SASSAFRAS. A tree, usually small and slender, but sometimes with a trunk 3 ft. in diameter and 125 ft. high. Leaves oval, entire, mitten-shaped or 3-lobed, downy when young but becoming smooth with age, dark green above, paler below, petiolate. Racemes several in a cluster, peduncled; flowers yellow. Stamens about as long as the sepals. Fruit dark blue, ovoid, on thickened red pedicels. All parts of the tree aromatic. Trees producing pistillate flowers rare. Common. The wood is valuable for cabinet making, and an aromatic oil is extracted from the bark.*

II. BENZOIN Fabric.

Shrubs. Leaves deciduous, entire. Flowers in lateral, sessile clusters, appearing before the leaves, dicœcious or somewhat monœcious. Involucre of 4 scales. Stamens 9 in the staminate

flowers; filaments slender. Pistillate flowers with 12–15 abortive stamens and a single globose ovary with a short style.*

1. B. æstivale Nees. Spice Bush. A shrub, 5–15 ft. high, with smooth bark and slender twigs. Leaves oblong-obovate, acute at the base, pale and downy beneath, becoming smooth when old; petioles short. Flowers about as long as the pedicels, yellow, very fragrant. Ovary about as long as the style. Fruit an obovoid, red drupe, about $\frac{1}{3}$ in. long, on a slender pedicel. Banks of streams and damp woods. Twigs and leaves quite aromatic.*

39. PAPAVERACEÆ. Poppy Family

Annual or perennial herbs, often with milky juice. Leaves sometimes all basal; stem leaves usually alternate without stipules. Flowers bisexual, regular or irregular. Sepals usually 2, shed as the flower opens. Petals 4–12, falling early. Stamens numerous or 6 (in 2 sets), 4, or 2. Carpels 2–16. Fruit a capsule.

I. ESCHSCHOLTZIA Cham.

Annual or perennial herbs. Leaves pale or bluish-green, usually cut into very narrow divisions. Sepals united into a pointed cap, which falls off in one piece as the flower opens. Petals 4, orange or yellow. Stamens many, with long anthers. Stigmas 2–6, spreading. Pods long and slender, grooved. Receptacle often surrounded by a rim on which the calyx rests.

1. E. californica Cham. Annual or perennial, with rather succulent leafy stems. Flowers large and showy, yellow or orange-yellow. Receptacle top-shaped, with a broad rim. Cultivated from California.

II. SANGUINARIA L.

Perennial. Rootstock thick, horizontal; joints and scars of previous growths persistent several years; juice orange-colored. Leaves on long petioles, kidney-shaped. Scape 1-flowered. Sepals 2, falling off as the flower opens. Petals 8–12. Ovary 1; stigmas 2. Capsule oblong, seeds crested.*

1. S. canadensis L. Bloodroot. Leaves and scape with a bloom; leaves palmately 5–9-lobed, lobes rounded or toothed; scapes naked, nearly as long as the petioles. Flowers white, 1 in. or more wide.

Petals oblong or obovate, quickly deciduous. Capsule 1-celled, 2-valved, the valves separating from the persistent placentæ at maturity. In rich, open woods.*

III. CHELIDONIUM L.

Erect, branched, perennial herbs, with yellow juice. Leaves much divided. Flowers yellow. Sepals 2, falling as the flower opens. Petals 4. Ovary 1-celled; style dilated at the top, with 2 joined stigmas. Capsule linear.

1. C. majus L. CELANDINE. Stem 1–2 ft. high, brittle, slightly hairy, leafy. Leaves once or twice pinnate. Flowers small. A rather common weed in yards and along fences. Naturalized from Europe.

IV. PAPAVER L.

Annual or perennial herbs with milky juice. Stem erect, smooth, or rough-hairy, branching above. Leaves more or less lobed or dissected. Flower buds nodding, flowers showy. Sepals commonly 2, falling off as the flower opens. Petals 4–6. Stamens many. Stigma disk-like; ovules many, borne on many inwardly projecting placentæ.*

1. P. somniferum L. OPIUM POPPY. Annual. Stem erect, branched above, smooth and with a bloom, 2–3 ft. high. Leaves oblong, irregularly lobed or cut, sessile, clasping. Flowers nearly white, with a purple center, large and showy, on long peduncles. Capsule globose, seeds minutely pitted. About old gardens and waste places. Cultivated in southern Asia, where the juice of the capsules is dried to make opium.*

2. P. Rhœas L. CORN POPPY. Annual. Stem erect, hairy, 1–3 ft. high. Lower leaves petioled, upper ones sessile, all pinnately cut, the lobes serrate. Corolla scarlet, often with a dark center, 2–4 in. in diameter. Capsule smooth, obovoid. Waste ground, sometimes in fields. Introduced from Europe and often cultivated.

3. P. dubium L. SMOOTH-FRUITED POPPY. Annual. Stem slender, branching, 1–2 ft. tall. Leaves pinnatifid, the lower petioled, the upper sessile. Flowers large and showy, usually red; capsule long-obovoid, smooth. In cultivated ground. Both this and No. 1 are often cultivated in gardens and produce double flowers.*

4. P. orientale L. ORIENTAL POPPY. A large, rough-hairy perennial. Leaves large, deep green, almost pinnate. Flower very large, deep red. Cultivated from the eastern Mediterranean region.

5. P. nudicaule L. Iceland Poppy. A delicate but rough-hairy perennial plant. Leaves all basal, pale, pinnately cut. Flowers yellow-orange or white, borne singly on rather slender, hairy scapes. Cultivated from Europe.

V. ADLUMIA Raf.

A delicate climbing biennial. Leaves thrice-pinnate, cut-lobed. Sepals 2, very small. Petals 4, all united into a corolla which is slightly heart-shaped or 2-knobbed at the base, remaining as a spongy covering over the small, few-seeded pod.

1. A. fungosa Greene. Mountain Fringe, Allegheny Vine. Climbing several feet high by the leafstalks. Flowers pinkish-white. Rocky hillsides, often cultivated.

VI. DICENTRA Bernh. (BICUCULLA)

Smooth, delicate herbs, with watery juice. Leaves compound in threes and finely cut. Flowers racemed, nodding. Sepals 2, small and scale-like. Petals 4, slightly united to form a heart-shaped or 2-spurred corolla (Fig. 17), the inner pair spoon-

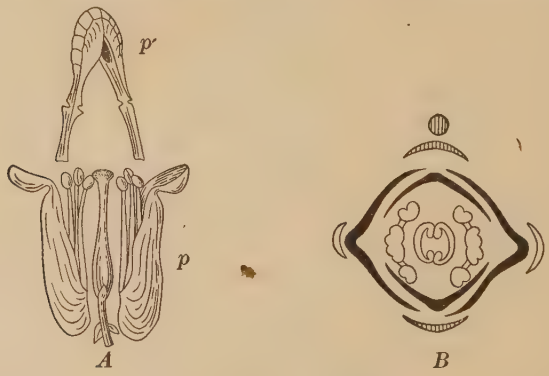


Fig. 17. Flower of *Dicentra*

A, view of flower partly dissected: *p*, the larger outer petals; *p'*, the spoon-shaped inner petals. *B*, floral diagram. (After Le Maout and Decaisne)

shaped, inclosing the stamens and pistil. Stamens 6; the filaments somewhat united into 2 sets, and the anthers in 2 sets close to the stigma. Stigma 2-crested. Pod 10–20-seeded.

1. D. Cucullaria Bernh. Dutchman's Breeches, Breeches Flower. A low, stemless perennial, with a delicate scape and a cluster of basal leaves with linear divisions, from a sort of bulb made of small, scaly grains. Flowers in a 4–10-flowered simple raceme, not fragrant. Spurs of the corolla longer than the pedicels; corolla mostly white with a yellowish tip. Rich woods, common.

2. D. canadensis Walp. Squirrel Corn, Wild Hyacinth. A low, stemless perennial, with scape and leaves much as in No. 1, and with small yellow tubers looking like grains of corn scattered along the underground shoots. Corolla only heart-shaped at the base, whitish or flesh-colored, very fragrant. Rich woods.

3. D. spectabilis Lem. Bleeding Heart, Ear Drops. Stems branching, recurved. Leaves large, twice compound in threes, the divisions rather broad, like those of the common peony. Racemes long, drooping, many-flowered. Flowers large, heart-shaped, bright pink. Cultivated from China.

VII. CORYDALIS Medic. (CAPNOIDES)

Leafy-stemmed biennial herbs (the American species). Leaves much divided, alternate or nearly opposite. Racemes terminal or opposite the leaves. Sepals 2, small. Petals 4; corolla with a single spur at the base, on the upper side. Capsule many-seeded.

1. C. sempervirens L. Pale Corydalis. Plant erect, covered with a bloom. Flowers pink-purple with yellow tips. Spur of the corolla very short and rounded. Rocky woods.

2. C. aurea Willd. Golden Corydalis. A low, spreading plant, finally ascending. Corolla bright yellow, 1–2 in. long; the spur shorter than the pedicel, somewhat bent. Shaded, rocky banks.

40. CRUCIFERÆ. Mustard Family

Herbs with pungent, watery juice, and alternate leaves without stipules. Sepals 4, often falling off early. Petals usually 4, arranged in the form of a cross. Stamens 6, the 2 outer ones shorter than the 4 inner ones. Fruit generally a pod, divided into 2 cells by a thin partition which stretches across from one to the other of the 2 placentæ. The flowers throughout the family are so much alike that the genera and species cannot usually be determined without examining the tolerably mature fruit.

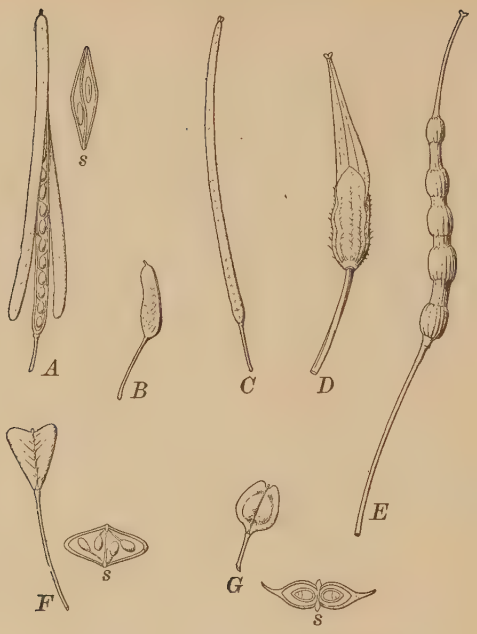


FIG. 18. Types of pods of *Cruciferæ*

A, flattened pod of *Arabis*, seeds in a single row in each cell: *s*, cross section of pod, showing flattening parallel to the partition. *B*, pod of *Radicula palustris*, seeds in several rows. *C*, nearly cylindrical pod of *Sisymbrium*. *D*, beaked pod of white mustard (*Sinapis alba*). *E*, dried necklace-shaped and beaked pod of radish (*Raphanus Raphanistrum*). *F*, flattened pod of shepherd's purse (*Capsella Bursa-pastoris*): *s*, cross section, showing flattening at right angles to the partition. *G*, flattened pod of *Lepidium campestre*; *s*, cross section, showing flattening at right angles to the partition. (The pods natural size, the sections somewhat magnified.) (After Cosson and De Saint-Pierre)

A

Pods short and flattened, contrary to the partition, splitting open when ripe.

Pod roundish.	Lepidium, IV
Pod triangular, inversely heart-shaped.	Capsella, V

B

Pods globular or cylindrical, splitting open when ripe.

(*a*) Pods globular. Flowers yellow.	Lesquerella, III

(*b*) Pods cylindrical; seeds ellipsoid. Flowers very small, yellow. Sisymbrium, VIII

(*c*) Pods cylindrical; seeds globular. Flowers of moderate size, yellow. Brassica, VII

(*d*) Pods cylindrical; seeds in 2 rows; flowers white. Or pods ovoid or ellipsoid; flower yellowish. Aquatic plants, or growing in wet soil. Radicula, IX

(*e*) Pods cylindrical or angled; seeds in a single row, flattened. Flowers yellow. Barbarea, X

C

Pods elongated, often jointed, tapering toward the tip, never splitting open. Raphanus, VI

D

Pods flattened parallel to the partition, splitting open when ripe.

(*a*) Wild species; leafy-stemmed; growing in or near water. Pods linear. Cardamine, XII

(*b*) Wild species; stems naked below, bearing only 2 or 3 leaves. Pods lanceolate. Dentaria, XI

(*c*) Wild species; leafy-stemmed; growing on dry ground or rocks. Pods linear; seeds usually winged or margined. Arabis, XIII

(*d*) Cultivated species. Pods round or roundish. Lobularia, I

(*e*) Cultivated species; covered with a grayish down of star-shaped hairs. Pods cylindrical. Matthiola, II

I. LOBULARIA Desv. (KONIGA)

Perennial, though usually growing as an annual. Stems branching, diffuse; branches slender. Leaves small, entire, downy, with forked hairs. Flowers small, white, in numerous terminal racemes. Petals obovate, entire, twice as long as the sepals. Filaments enlarged below. Pod round, compressed; seeds 1 in each cell.*

1. L. maritima Desv. Sweet Alyssum. Stem weak, diffuse, ascending, minutely downy. Lower leaves narrowed into a petiole, the upper sessile. Racemes erect, many-flowered. Flowers fragrant, pedicels ascending. Pod often pointed. Common in cultivation and often run wild.*

II. MATTHIOLA R. Br.

Herbaceous or shrubby oriental plants, covered with a down composed of star-shaped hairs. Flowers in showy racemes of many colors, ranging from white to crimson. Stigmas large and spreading. Pods nearly cylindrical, except for a prominent midrib on each valve.

1. M. incana R. Br. Common Stock, Gillyflower. Biennial or perennial, with somewhat woody stems. Cultivated in greenhouses and gardens.

III. LESQUERELLA Wats.

Low herbs with stellate hairs. Leaves simple. Flowers in racemes, mostly yellow. Pod globular-inflated, with a translucent partition nerved from the apex to the middle. Seeds few, several or many, flattened, marginless or nearly so.

1. L. globosa Wats. Annual or biennial. Slender, somewhat branched, 6–20 in. high, covered with fine stellate hairs. Basal leaves 1–1½ in. long, oblong-obovate, obtuse. Stem leaves smaller, linear or oblong, sessile. Raceme finally elongated with thread-like diverging pedicels. Flowers light yellow. Style slender, much longer than the small globose pod. Rocky banks and open places S. and W.

2. L. argentea Pursh. Silvery Bladder Pod. Biennial or perennial, 6–18 in. high, densely stellate-hairy. Leaves linear to oblanceolate, blunt, entire, the lower ones 2–3 in. long. Flowers yellow. Pods downy, on recurved pedicels. Plains W.,

IV. LEPIDIUM L.

Annual. Stem erect, or sometimes diffuse. Leaves entire, toothed, or pinnately divided. Flowers in a terminal raceme, small, white. Petals short, sometimes wanting. Stamens 2, 4, or 6. Pod rounded or obcordate, flattened contrary to the partitions.*

1. L. virginicum L. Peppergrass, Birds' Pepper, Tongue Grass. Stem erect, smooth, much branched, 1–2 ft. high. Lower leaves obovate in outline, pinnately cut with dentate lobes; upper leaves lanceolate, dentate, slightly downy. Flowers on slender pedicels; petals present, sometimes reduced in the later flowers. Stamens 2. Pod round. A weed growing in waste places.*

2. L. campestre R. Br. Field Cress. Annual or biennial. Stem erect, branching above, downy, 8–18 in. high. Basal leaves entire or

pinnately cut toward the base, obtuse; stem leaves oblong or lanceolate, entire or somewhat toothed, with an arrow-shaped clasping base. Flowers white or yellowish, on stout pedicels. Pods ovate, winged, slightly notched, tipped with a very small persistent style. Fields and waste ground, becoming a troublesome weed. Naturalized from Europe.

V. CAPSELLA Medic. (BURSA)

Annual. Stem erect, downy, with branched hairs. Racemes terminal, becoming elongated in fruit. Flowers small, white. Pod obcordate or triangular, flattened contrary to the partition, shorter than the spreading pedicels.*

1. C. Bursa-pastoris Medic. Shepherd's Purse. Root long and straight. Stem branching above, downy below, smooth above. Lower leaves forming a rosette at the base of the stem, irregularly lobed or pinnately cut; stem leaves lanceolate, clasping, toothed or entire. Sepals downy, about ½ as long as the petals. Pod triangular, notched, or cordate at the apex. Seeds several in each cell. A common weed.*

VI. RAPHANUS L.

Annual or biennial herbs. Basal leaves lyrate. Flowers in long racemes, white or yellow, purple-veined. Sepals erect. Pods rather long, slender-beaked, not splitting open but sometimes breaking across into 1-seeded joints.

1. R. Raphanistrum L. Wild Radish, Jointed Charlock. A stout, hairy annual, 1–2 ft. high. Leaves cut into remote segments, which are coarsely toothed or serrate; terminal segment largest. Flowers yellow, turning whitish or purplish. Pods necklace-shaped, and with a long beak. A common weed eastward. Naturalized from Europe.

2. R. sativus L. Common Radish. Similar to No. 1, but with pink or white flowers. Root fleshy, conical or turnip-shaped. Pod fleshy, 2–3-seeded, the beak often longer than the seed-bearing portion. Cultivated from Asia and occasionally self-sown in cultivated ground.

VII. BRASSICA L.

Branching herbs. Leaves often pinnately cut. Flowers in racemes, rather large, yellow. Sepals spreading. Pods nearly cylindrical, sometimes tipped with a beak which does not open. Seeds globular.

1. B. alba Boiss. White Mustard. Stem 2–5 ft. high, with reflexed hairs. Upper leaves pinnately cut. Pods borne on spreading pedicels, bristly, with a sword-shaped, 1-seeded beak occupying more than half their length. Seeds pale. Cultivated from Europe and introduced to some extent.

2. B. arvensis Ktze. Charlock. Stem 1–2 ft. high; it and the leaves rough-hairy. Upper leaves rhombic, barely toothed. Flowers $\frac{1}{2}$–$\frac{3}{4}$ in. across, somewhat corymbed, bright yellow. Pods knotty, spreading, at least $\frac{1}{3}$ of each consisting of a 2-edged, 1-seeded beak. A showy, troublesome weed in grain fields. Naturalized from Europe.

3. B. juncea Cosson. Similar to the preceding, but nearly or quite smooth. Pedicels slender. Beak slender, conical, not containing a seed. Naturalized from Asia and becoming very abundant eastward.

4. B. nigra Koch. Black Mustard. Stem 3–6 ft. high, somewhat hairy. Lower leaves lyrate, with the terminal lobe much the longest; stem-leaves linear-lanceolate, entire or toothed, smooth. Pods awl-shaped, 4-angled, smooth, lying against the stem; seeds brownish, more biting than in No. 1. Cultivated from Europe and introduced.

VIII. SISYMBRIUM L.

Annual or biennial herbs. Radical leaves spreading; stem leaves alternate, often eared at the base. Flowers in loose racemes, usually yellow, often bracted. Pods generally narrowly linear, cylindrical, or 4–6-angled; seeds many, ellipsoid, not margined.

1. S. officinale Scop., var. **leiocarpum.** Hedge Mustard. Stems branching, stiff. Leaves runcinate-toothed or lobed. Flowers very small, pale yellow. Pods somewhat 6-sided, awl-shaped, smooth, closely pressed against the stem. An unsightly weed in waste ground. Naturalized from Europe.

2. S. canescens Nutt. Tansy Mustard. Stem 1–2 ft. high. Leaves twice pinnately cut, usually covered with grayish down. Flowers very small, yellowish. Pods oblong, club-shaped, 4-angled, borne on pedicels projecting almost horizontally from the stem, in long racemes. Common westward.

IX. RADICULA Hill. (RORIPA)

Annual or biennial, mostly aquatic plants. Stems erect or diffuse, often widely branching. Leaves simple, pinnately lobed. Flowers small, white or yellow. Sepals spreading.

Stamens 1–6. Pod short and broad or nearly linear; seeds numerous, in 2 rows in each cell.*

1. R. Nasturtium-aquaticum B. & R. WATERCRESS. Aquatic herbs. Stems smooth, diffuse, rooting at the joints. Leaves with 3–9 rounded, pinnate lobes, the terminal lobe much the largest. Racemes elongating in fruit. Petals white, twice the length of the sepals. Pods linear, $\frac{1}{2}$–$\frac{3}{4}$ in. long, on slender, spreading pedicels. In ditches and slow streams. Often used for salad.*

2. R. sinuata Greene. SPREADING YELLOW CRESS. Perennial. Stems low and spreading. Leaves oblong or lanceolate, pinnately cleft, the lobes obtuse. Flowers yellow, about $\frac{1}{6}$ in. in diameter. Pods linear oblong, $\frac{1}{3}$–$\frac{1}{2}$ in. long. River bottoms and moist ground W.

3. R. palustris Mœnch. YELLOW WATERCRESS. Annual or biennial. Stem erect, branched, slightly downy. Leaves irregularly lyrate, the lower petioled, the upper sessile. Flowers small; petals yellow. Pods linear, spreading, longer than the pedicels. In wet places.*

4. R. Armoracia Robinson. HORSE-RADISH. A coarse herb, with large leaves, from stout, long, cylindrical rootstocks filled with a very sharp, biting juice. Basal leaves long-petioled, linear-oblong, obtuse, regularly scalloped; stem-leaves sessile. Racemes in panicles. Pods obovoid, on long, slender pedicels; seeds seldom or never ripening. Probably from Europe; cultivated and often introduced in damp ground.

X. BARBAREA R. Br.

Mostly biennials, somewhat resembling *Radicula*. Flowers yellow. Pod elongated, linear, cylindrical, or somewhat 4-sided. Style short. Seeds in 1 row in each cell, not margined.

1. B. vulgaris R. Br. WINTER CRESS, YELLOW ROCKET. Smooth, with tufted stems 1–2 ft. high. Lower leaves petioled, pinnately cut, with 1–4 pairs of lateral divisions and a rounded, much longer terminal one; upper leaves nearly or quite sessile. Flowers $\frac{3}{8}$ in. in diameter or less. Pods erect or spreading. Fields and waste ground. Introduced from Europe into the eastern and central states.

XI. DENTARIA L.

Stems naked below, 2–3-leaved above, from a thickish, more or less knotted or interrupted rootstock. Flowers rather large, in early spring. Pod lance-linear, flattish; seeds in 1 row, wingless; seedstalks broad and flat.

1. D. diphylla L. Two-Leaved Toothwort, Pepper Root, Crinkle Root. Rootstock long, often branched, toothed, eatable, with a flavor like that of cress or radish. Stem leaves 2, close together, each composed of 3 ovate-diamond-shaped and toothed or crenate leaflets; the basal leaf like the stem leaves. Flowers white. Damp woods.

2. D. laciniata Muhl. Crow's-Foot. Rootstock short, necklace-like. Stem leaves 3-parted; basal leaf often absent. Flowers white or rose color. Woods.

XII. CARDAMINE L.

Annual or perennial. Rootstock often scaly or bulb-bearing. Stem erect or ascending, usually smooth. Leaves more or less divided. Flowers in terminal racemes, white or purple. Petals rather large. Stamens 6. Fruit a linear, flattened pod; seeds several, in a single row in each cell.*

1. C. rhomboidea DC. Bulbous Cress. Perennial. Root tuberous. Stem simple, erect, smooth, without runners, 9–18 in. tall. Lower leaves long-petioled, ovate, orbicular, or heart-shaped, often angled or toothed; the upper short-petioled or sessile, lanceolate or oblong, toothed or entire. Pedicels $\frac{1}{2}$–1 in. long. Petals white, $\frac{1}{4}$–$\frac{1}{3}$ in. long. Pod erect, linear-lanceolate, tipped by the persistent style; seeds round-oval. Cool, wet places.*

2. C. pennsylvanica Muhl. Bitter Cress. Annual. Stem slender, erect, simple, or with a few slender branches, 6–15 in. tall. Leaves mostly in a cluster at the base of the stem, pinnately divided, the terminal lobe roundish, the lateral lobes narrower, somewhat hairy above; stem leaves nearly linear. Flowers small. Petals white, longer than the sepals. Stamens 4. Pods linear, erect on erect pedicels, about 1 in. long; seeds oval. In wet places.*

XIII. ARABIS L.

Annual or perennial herbs, smooth, or with forked or star-shaped hairs. Basal leaves spatulate; stem leaves sessile. Flowers usually white. Petals entire, usually with claws. Pods linear, flattened; seeds often margined or winged.

1. A. hirsuta Scop. A rough-hairy, erect, leafy-stemmed biennial, 1–2 ft. high. Leaves simple; stem leaves oblong or lanceolate, entire or toothed, somewhat clasping, often with an arrow-shaped base. Flowers small, greenish-white, the petals somewhat longer than the sepals. Pods and pedicels upright. Style almost wanting. Seeds roundish, somewhat wing-margined. Rocks, N.

2. A. lævigata Poir. A smooth, leafy-stemmed biennial, 1–2 ft. high, covered with a bloom. Stem leaves lance-linear, clasping. Flowers small and whitish, the petals hardly longer than the sepals. Pods 2–3 in. long, flattened, spreading, and recurved; seeds broadly winged. Rocks.

3. A. canadensis L. Sickle Pod. An upright, leafy-stemmed biennial, 2–3 ft. high, simple or slightly branching above, sometimes slightly hairy at the base. Stem leaves sessile, oblong-lanceolate, pointed at both ends, downy; the lower ones toothed. Flowers small, whitish, the petals twice as long as the sepals. Pods scythe-shaped, much flattened, hanging from hairy pedicels; seeds broadly winged. Rocky hillsides.

41. CAPPARIDACEÆ. Caper Family

Herbs (when growing in cool temperate regions), with bitter or nauseous juice. Leaves alternate, usually palmately compound. Flowers often not actinomorphic, usually bisexual. Sepals 4–8. Petals 4 or wanting. Stamens 6 or more. Ovary and pod 1-celled, with 2 rows of ovules; seeds kidney-shaped.

I. POLANISIA Raf.

Ill-smelling annual plants covered with glandular or clammy hairs. Sepals distinct, spreading. Petals with claws, notched at the tip. Stamens 8–32, of various lengths. Receptacle not lengthened. Pod linear or oblong, rather large, many-seeded.

1. P. graveolens Raf. A very strong-scented, leafy, branching herb, 6–15 in. high. Leaves with 3 oblong leaflets. Flowers small, pinkish and yellowish-white, in the axils of leafy bracts, in terminal racemes. Stamens 8–12, not much longer than the petals. Pod about 2 in. long, slightly stalked. Gravelly banks.

II. CLEOME L.

Mostly annual herbs. Stems branched. Leaves petioled, simple, or with 3–7 entire or serrate leaflets. Flowers in bracted racemes. Sepals 4, often persistent. Petals 4, often long-clawed, nearly equal, entire. Stamens 6, filaments thread-like, usually projecting much, but sometimes 1–3 much shorter than the others, inserted on the short receptacle. Ovary on a

short stalk with a small gland at its base. Fruit a slender capsule on an elongated stalk.*

1. C. serrulata Pursh. Rocky Mountain Bee Plant, Stinking Clover. A smooth plant 2 ft. or more high. Leaves with 3 leaflets. Flowers pink, showy, in leafy-bracted racemes. Pod oblong to linear, 1–2 in. long. Cultivated as an ornamental plant and also for bees. Common in a wild condition W.

42. RESEDACEÆ. Mignonette Family

Annual or perennial herbs, rarely shrubs. Leaves alternate, simple or pinnately cut. Flowers racemed or spiked, bracted. Calyx 4–7-parted, often not actinomorphic. Petals 4–7, hypogynous, often unequal and cleft or notched. Stamens usually many, borne on a large one-sided hypogynous disk. Ovary of 2–6 carpels, which are more or less united into a single 1-celled, many-seeded, several-lobed or -horned pistil, which opens at the top before the seeds ripen.

RESEDA L.

Annual. Stems diffuse, widely branched. Leaves sessile, entire or lobed, smooth. Flowers in close racemes or spikes. Petals 4–7, toothed or cleft. Stamens 8–30, inserted at one side of the flower. Capsule 3–6-lobed.*

1. R. odorata L. Mignonette. Stem widely diffuse, 6–12 in. high, smooth. Leaves wedge-shaped, entire or 3-lobed. Flowers small, greenish-yellow, very fragrant. Petals deeply 7–13-cleft. Often cultivated. From Egypt.*

43. SARRACENIACEÆ. Pitcher Plant Family

Perennial, apparently stemless, marsh herbs. Leaves tubular or trumpet-shaped. Flowers single, nodding, on a naked or bracted scape. Sepals 4–5, colored, persistent. Petals 5, deciduous, or sometimes wanting. Stamens numerous. Pistil compound, 5-celled, many-ovuled; style terminal, nearly as broad as the flower, shield-shaped.*

SARRACENIA L.

Rootstock short, horizontal; scape naked. Leaves trumpet-shaped, with a wing extending nearly to the base and a broad blade at the apex; tube hairy within, with downward-pointing, stiff hairs. Calyx 3-bracted. Petals obovate, drooping or incurved. Style umbrella-shaped, 5-angled; stigmas at the hooked angles of the style on the under surface. Capsule globose, rough. [The tubular leaves usually contain more or less water and dead insects, the latter having been attracted by a honey-like secretion near the opening.]

1. S. purpurea L. Sidesaddle Flower. Leaves ascending, curved, broadly winged, purple-veined, 4–8 in. long; blade erect, round-cordate, hairy on the inner side. Scapes 12–18 in. tall; flower deep purple, about 2 in. broad; style yellowish. Mossy swamps.*

44. SAXIFRAGACEÆ. Saxifrage Family

Herbs or shrubs. Leaves alternate or opposite, generally without stipules. Sepals 4 or 5, more or less joined with each other and not usually hypogynous. Petals as many as the sepals and alternate with them. Stamens as many as the petals and alternate with them, or 2–10 times as many. Ovary usually of two carpels, united only at the base or more or less throughout. Fruit generally a 1–2-celled capsule, sometimes a berry; seeds many, with endosperm.

I. SAXIFRAGA L.

Herbs with simple or palmately cut leaves and generally cymose or panicled flowers. Sepals 5, more or less united. Petals 5, entire, inserted on the calyx tube. Stamens 10. Capsule consisting of 2 (sometimes more) ovaries, united at the base, separate and diverging above.

1. S. pennsylvanica L. Swamp Saxifrage. Perennial. Leaves 4–8 in. long, oblong-lanceolate and tapering to the base, slightly toothed. Scape 1–2 ft. high, bearing an oblong cluster of small greenish flowers, at length diffusely panicled. Petals greenish-yellow

(rarely crimson), linear-lanceolate, hardly longer than the calyx lobes. Boggy ground.

2. S. virginiensis Michx. Early Saxifrage, Mayflower. Perennial. Apparently stemless, with a cluster of spatulate, obovate, or wedge-shaped basal leaves, and a scape 3–9 in. high, which bears a dense cluster of small white flowers, becoming at length a panicled cyme. Petals white, oblong, much longer than the calyx. Rocks and dry hillsides N.

II. TIARELLA L.

Perennial. Flowers white, in racemes. Calyx white, 5-parted, nearly hypogynous. Corolla of 5 very narrow petals, with slender claws, alternating with the calyx lobes. Stamens 10, springing from the calyx tube and extending outside the flower. Styles 2, long and slender; ovary 1-celled, 2-beaked. In fruit one of the carpels grows to be much larger than the other, thus making up the main bulk of the thin, dry pod, which has a few seeds attached near the bottom.

1. T. cordifolia L. False Miterwort. Stem 5–12 in. high, usually leafless, sometimes with 1 or 2 leaves. Rootstock bearing runners in summer. Leaves heart-shaped, sharply lobed, the lobes with acute or mucronate teeth, somewhat hairy above, downy beneath. Raceme short and simple. Rocky woods, especially N.

III. HEUCHERA L.

Perennials, with a tall scape and roundish, heart-shaped basal leaves. Flowers rather small, greenish or purplish, in a long panicle. Calyx 5-cleft, the tube somewhat perigynous. Petals 5, small, spatulate, inserted with the 5 stamens on the margin of the calyx tube. Capsule 1-celled, 2-beaked, splitting open between the beaks.

1. H. americana L. Common Alum Root. Scapes 2–4 ft. high, rather slender, often several from the same root, hairy and glandular. Basal leaves large and long-petioled, abundant, somewhat 7-lobed. Flowers whitish with a tinge of purple, in a loose panicle. Stamens projecting considerably outside the flower, their anthers of a bright terra cotta color. The root is very astringent and is somewhat used as a home remedy. Shaded banks, fence rows, and thickets; common W.

IV. MITELLA L.

Delicate perennial herbs. Flowers small, pretty, in a simple raceme or spike. Calyx 5-cleft, slightly perigynous. Petals 5, cut-fringed, inserted on the throat of the calyx tube. Stamens 5 or 10, not projecting from the calyx tube. Styles 2, very short. Ovary and pod 2-beaked, globular, 1-celled.

1. **M. diphylla** L. Two-Leaved Bishop's Cap, Fringe Cup, Fairy Cup. Stemless, with long-petioled, roundish-cordate root leaves, and a scape about 1 ft. high, bearing 2 opposite, nearly sessile leaves. Flowers many, racemed, white. Woods.

V. PHILADELPHUS L.

Shrubs. Leaves simple, opposite, 3–5-ribbed, petioled, without stipules. Flowers solitary or in cymes, large, white. Calyx tube top-shaped, the epigynous limb 4–5-parted, persistent. Petals 4–5, rounded or obovate. Stamens 20–40, shorter than the petals. Ovary 3–5-celled, many-seeded; styles 3–5, more or less united.*

1. **P. grandiflorus** Willd. Large-Flowered Syringa. Shrub, 6–10 ft. high; branches downy. Leaves ovate or ovate-oblong, taper-pointed, sharply serrate, downy, 3-ribbed. Flowers solitary or 2–3 together, white, 1½–2 in. broad, not fragrant. Calyx lobes ovate, taper-pointed, about twice as long as the tube. On low ground S., and cultivated.*

2. **P. coronarius** L. Garden Syringa. Shrub, 8–10 ft. high. Leaves oval or ovate, obtuse at the base, acute at the apex, remotely toothed, smooth above, downy beneath. Flowers in terminal racemes, creamy white, 1–1½ in. wide, very fragrant. Calyx lobes ovate, acute, longer than the tube. Common in cultivation. From southern Europe.*

VI. DEUTZIA Thunb.

Shrubs with simple, opposite leaves, without stipules. Flowers all bisexual and alike, racemed or panicled, showy. Calyx lobes 5. Petals 5. Stamens 10, 5 long and 5 short; filaments flat and 3-pronged, the middle prong bearing an anther. Styles 3–5, slender. Pod 3–5-celled.

1. **D. gracilis** Sieb. & Zucc. About 2 ft. high, loosely spreading. Leaves ovate-lanceolate, sharply serrate, smooth. Flowers white, very numerous. Cultivated from Japan, often in greenhouses.

VII. RIBES L.

Shrubs. Leaves palmately veined and lobed, sometimes with stipules. Calyx tube egg-shaped, its 5 epigynous lobes usually colored like the petals. Petals 5, small, generally inserted on the throat of the calyx tube. Stamens 5, inserted with the petals. Styles 2; ovary 1-celled, with 2 placentæ on its walls, becoming in fruit a pulpy (usually eatable) berry.

1. R. Cynosbati L. Prickly Wild Gooseberry. Spines in pairs. Leaves long-petioled, downy, heart-shaped, cut-dentate. The single style and the stamens not projecting from the calyx tube. Berries generally prickly, brownish-purple, pleasant-flavored.

2. R. gracile Michx. Slender Gooseberry. Spines slender, solitary, or in pairs or threes. Leaves with slender petioles, somewhat downy when young, round, the base truncate or obtuse, 3–5-lobed, the divisions obtuse and toothed. Flowers often in threes, white or greenish, drooping. Calyx lobes longer than the tube; stamens decidedly projecting from the tube. Berries smooth, reddish-purple. Dry or rocky soil W.

3. R. rotundifolium Michx. Smooth Wild Gooseberry. Spines few and short, prickles few or absent. Leaves roundish, lobed, with the lobes crenate-dentate, often downy. Peduncles slender; flowers inconspicuous. Calyx lobes reflexed. Styles and stamens projecting decidedly from the calyx tube. Berries smooth.

4. R. oxyacanthoides L. Northern Gooseberry. Spines usually solitary, often numerous. Leaves petioled, their lower surfaces and petioles commonly downy. Flowers 1–3 together, on short pedicels, greenish-purple or white. Berry $\frac{1}{3}$–$\frac{1}{2}$ in. in diameter, smooth, reddish-purple. Low grounds and damp woods N.

5. R. americanum Mill. Wild Black Currant. Branches thornless, erect. Leaves resinous-dotted, somewhat heart-shaped, 3–5-lobed, toothed. Flowers large, whitish. Calyx tubular-bell-shaped, smooth. Fruit round-ovoid, black, smooth. In woods.

6. R. vulgare Lam. Red Currant. Stems more or less reclining. Leaves somewhat heart-shaped, obtusely 3–5-lobed. Racemes drooping. Limb of the calyx wheel-shaped. Berries acid, eatable, red or light amber-colored. Cultivated from Europe; also somewhat naturalized.

7. R. odoratum Wendland. Golden Currant, Flowering C., Missouri C., Clove Currant. A much taller shrub than the common red currant. Leaves 3-lobed, toothed. Racemes short and loose. Tube of the yellow calyx much longer than its limb. Flowers very fragrant. Fruit brownish-black, barely eatable.

45. PLATANACEÆ. Sycamore Family

Trees, with simple, alternate, petioled leaves, with stipules; the bases of the petioles covering the buds. Flowers monœcious, in axillary, long-peduncled, globose heads. Calyx and corolla very inconspicuous, each consisting of 3–8 minute scales, or wanting. Stamens as many as the sepals and opposite them. Pistils several, inversely conical, hairy at the base; styles long. Capsules 1-seeded.*

PLATANUS L.

Characters of the family.

1. P. occidentalis L. Sycamore, Buttonwood. A large tree, bark light-colored, smooth, peeling off in large, thin plates. Leaves large, round-heart-shaped, angularly lobed and toothed, densely white-woolly when young, becoming smooth with age; stipules large, toothed. Fruit in a globular, drooping head, which remains on the tree through the winter, dropping the seeds very slowly. Common on river banks and in swampy woods.*

46. ROSACEÆ. Rose Family

Herbs, shrubs, or trees. Leaves alternate or rarely opposite, simple or compound, with stipules. Calyx 5-lobed. Petals 5, rarely wanting, inserted with the stamens on the edge of a disk that lines the calyx tube. Stamens many, rarely 1 or few. Carpels 1 or more, distinct or united, superior or inferior. Fruit a pome, a drupe or group of drupes, or 1–several akenes, or follicles, rarely a berry or capsule. The relation of the parts of the flower to each other and to the receptacle is shown in Fig. 19.

A

Ripe carpels not inclosed within the calyx tube.

1. Fruit dry.
   (*a*) Carpels 1–5, inflated. Physocarpus, I
   (*b*) Pods 5–8, not inflated, 2–several-seeded. Spiræa, II

(*c*) Carpels 5–15 (usually 10), 1-seeded. Filipendula, X

(*d*) Akenes 2–6, styles not lengthening after flowering. Waldsteinia, VIII

(*e*) Akenes many, on a dry receptacle. Styles not lengthening. Potentilla, IX

(*f*) Akenes many, on a dry receptacle. Styles lengthening after flowering, forming tails to the akenes. Geum., XI

2. Fruit fleshy.

(*a*) Akenes several–many, becoming little drupes. Rubus, XII

(*b*) Akenes many, dry on ripening, on a fleshy, eatable receptacle. Fragaria, VII

(*c*) Pistil solitary, becoming a drupe Prunus, XIV

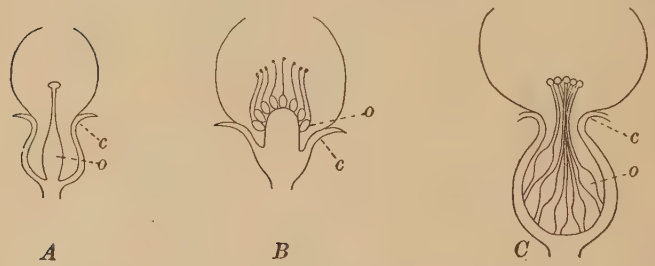


Fig. 19. Pistils in the Rose Family

A, *Prunus*-type; *B*, *Potentilla*-type; *C*, *Rosa*-type. *c*, calyx; *o*, ovary

B

Ripe carpels inclosed within the calyx tube.

1. Fruit a pome.

(*a*) Carpels more than 2-seeded; seeds covered with a mucilaginous pulp. Fruit 5-celled. Cydonia, III

(*b*) Carpels 2-seeded (except in some cultivated varieties); seeds without pulp. Fruit 5-celled. Pyrus, IV

(*c*) Carpels 2-seeded; fruit 10-celled. Amelanchier, V

2. Fruit not evidently a pome, or not at all so.
   (*a*) Trees or shrubs. Fruit with a stone usually of 2–5 bony 1-seeded carpels united. Cratægus, VI
   (*b*) Shrubs. Fruit with many akenes borne on the interior of a fleshy calyx tube. Rosa, XIII

I. PHYSOCARPUS Maxim. (OPULASTER)

Shrubs. Leaves simple, palmately veined and lobed, petioled. Flowers white, in terminal corymbs. Calyx spreading, 5-lobed. Petals 5. Stamens numerous. Pistils 1–5, short-stalked; stigma terminal; ovaries becoming inflated at maturity, 2–4-seeded, splitting open.*

1. P. opulifolius Maxim. Nine-Bark. A spreading shrub, 3–6 ft. high, the old bark separating into thin strips. Leaves petioled, broadly ovate or rounded, often heart-shaped, 3-lobed, the lobes doubly crenate-serrate; stipules deciduous. Corymbs terminal, peduncled, nearly globose, downy, many-flowered. Follicles 3–5, much longer than the calyx, smooth and shining, obliquely tipped by the persistent style. Banks of streams.*

II. SPIRÆA L.

Shrubs with simple leaves. Flowers perfect, in terminal or axillary racemes or panicles. Calyx 5-cleft, persistent. Petals 5. Stamens numerous. Pistils usually 5, free from the calyx and alternate with its lobes. Follicles not inflated, 2–several-seeded.*

1. S. salicifolia L. Willow-Leaved Spiræa. Shrubs 2–5 ft. high, branches smooth. Leaves lanceolate to oblong-ovate, smooth or nearly so, sharply serrate, base usually wedge-shaped, pale beneath; stipules deciduous. Flowers white or pink, panicle dense-flowered; follicles smooth. On low ground.*

2. S. cantoniensis Lour. Bridal Wreath. Shrubs 2–4 ft. tall; branches long, slender, and spreading. Leaves lanceolate, serrate, sometimes 3-lobed or pinnatifid, with a bloom beneath. Flowers white or pinkish, in axillary racemes or corymbs, often forming long wreaths. Follicles smooth. Cultivated from Europe.

3. S. tomentosa L. Hardhack. Erect shrubs. Stems densely downy, usually simple. Leaves simple, ovate or oblong, serrate, densely rusty-downy below, smooth and dark green above. Flowers

small, pink or purple, in a close panicle. Follicles 5, densely downy, several-seeded. On low ground S., and along fence rows and in pastures N., where it is a troublesome weed.*

III. CYDONIA L.

Trees or shrubs. Leaves simple, toothed or lobed, stipules deciduous. Flowers usually solitary, white or pink. Calyx tube urn-shaped, 5-lobed, its epigynous lobes acute, spreading, persistent. Petals 5. Stamens numerous, inserted with the petals on the calyx tube. Styles 2–5, mostly 5, united at the base; ovary 5-celled, seeds many in each cell. Fruit a pome, globose, usually depressed or hollowed at the extremities; flesh without hard grains.*

1. **C. vulgaris** Pers. QUINCE. Shrub 6–12 ft. high. Leaves oblong-ovate, acute at the apex, obtuse at the base, entire, downy below. Flowers large, white or pink. Fruit ovoid, downy. Cultivated.*

2. **C. japonica** Pers. JAPAN QUINCE. A widely branching shrub, 3–6 ft. high; branches with numerous straight spines. Leaves ovate-lanceolate, acute at each end, smooth and shining, serrulate; stipules conspicuous, kidney-shaped. Flowers in nearly sessile axillary clusters, bright scarlet. Fruit globose. Common in cultivation.*

IV. PYRUS L.

Trees. Leaves simple, stipules small, deciduous. Flowers in cymes, large, white or pink. Calyx urn-shaped, 5-cleft, its epigynous lobes acute. Petals rounded, short-clawed. Stamens numerous, borne with the petals on the calyx tube. Styles 5, distinct or slightly united at the base. Fruit a pome, with about 2 seeds in each carpel.*

B. Fl. species 2–5 (*Malus*); species 6 (*Aronia*); species 7, 8 (*Sorbus*).

1. **P. communis** L. PEAR. A tree, often very large; head usually pyramidal, branches often thorny. Leaves thick and leathery, ovate or oval, acute, finely serrate or entire, downy when young, becoming smooth with age; petioles slender. Cymes few–several-flowered, terminal, and at the ends of "fruit spurs" grown the previous season. Flowers white. Styles not united. Fruit obovoid, with hard gritty grains near the core. A European and Asiatic tree common in cultivation.*

2. P. angustifolia Ait. NARROW-LEAVED CRAB APPLE. A small tree, with smooth, light gray bark. Leaves lanceolate or oblong, serrate, downy when young, acute at the base, short-petioled. Corymbs few-flowered. Flowers pink, fragrant, about 1 in. broad. Styles smooth, distinct. Fruit nearly globose, about $\frac{3}{4}$ in. in diameter, very sour. In open woods, Pennsylvania, West, and South.*

3. P. coronaria L. AMERICAN CRAB APPLE. A small tree, with smooth bark. Leaves triangular or oval-lanceolate, acutish or rounded or a little heart-shaped at the base, cut-serrate and often somewhat 3-lobed, slender-petioled, soon smooth. Flowers large, few in a cluster, pale rose color, very sweet-scented. Fruit bright green, turning yellowish, sometimes $1\frac{1}{2}$ in. in diameter, flattened at right angles to the pedicels, very fragrant. Glades, western New York, West, and South.

4. P. ioensis Bailey. WESTERN CRAB APPLE. A small tree, much like *P. coronaria* but with the leaves white-downy beneath, ovate-lanceolate and narrowed at the base. Fruit dull green with light dots, about 1 in. in diameter. Thickets W.

5. P. Malus L. APPLE. A tree with a rounded top and dark-colored bark. Leaves oval or ovate, obtuse or pointed, dentate or nearly entire, rounded at the base, smooth above, downy beneath. Cymes few–many-flowered. Flowers large, white or pink. Calyx downy. Fruit depressed-globose to ovoid, hollowed at the base and usually at the apex. Cultivated from Europe and often running wild in old pastures, etc., E.*

6. P. arbutifolia L. f. CHOKEBERRY, CHOKE PEAR, DOGBERRY. A shrub, 5–8 ft. high. Leaves oblong or oblanceolate, finely serrate, downy beneath, short-petioled. Flowers in a downy compound cyme, small, white or reddish. Fruit pear-shaped or nearly globular, not larger than a currant, very dark purple, dry and puckery. There is also a smooth-leaved variety with black fruit. Swamps and damp thickets, especially N.E.

7. P. americana DC. AMERICAN MOUNTAIN ASH. A tall shrub or small tree. Leaves odd-pinnate. Leaflets oblong-lanceolate, taper-pointed, sharply serrate, smooth, bright green. Flowers small, white, in large flat, compound cymes. Fruit bright scarlet, not larger than currants. Common N. and often cultivated.

8. P. Aucuparia Ehrh. EUROPEAN MOUNTAIN ASH or ROWAN TREE. Larger than No. 7. Leaflets paler, downy beneath. Fruit larger, about $\frac{1}{2}$ in. in diameter. Cultivated from Europe.

V. AMELANCHIER Medic.

Shrubs or small trees, with smooth gray bark. Leaves simple, sharply serrate, petioled. Flowers white, in racemes.

Calyx tube 5-cleft, its lobes epigynous. Petals oblong. Styles 5, united below; ovary 5-celled, 2 ovules in each cell, often only 1 maturing. Fruit small, berry-like.*

1. **A. canadensis** Medic. SERVICE BERRY, JUNEBERRY, SHAD BUSH, SUGAR PLUM, SUGAR PEAR, WILD PEAR. A small tree, branches downy when young, soon becoming smooth. Leaves ovate to elliptical, finely and sharply serrate, acute at the apex, usually obtuse or cordate at the base. Racemes slender, many-flowered, appearing before or with the leaves. Flowers showy. Petals 4 or 5 times the length of the smooth calyx lobes. Fruit globose, dark red, edible. In rich woods. Extremely variable in height and in shape of leaves.*

2. **A. spicata** K. Koch. ROUND-LEAVED JUNEBERRY. Much like *A. canadensis*, but with the leaves broadly oval, ovate, or almost orbicular, and usually rounded at both ends. Woods and thickets, especially N.

VI. CRATÆGUS L.

Shrubs or small trees, mostly with numerous strong spines, wood very hard. Leaves serrate, lobed or deeply incised, petioled. Flowers white or pink, in terminal corymbs or sometimes solitary. Calyx tube urn-shaped, 5-cleft, the limb persistent. Petals round. Stamens few or many. Styles 1–5, distinct; ovules 1 in each cell. Fruit a small pome with bony carpels.* [The species are hard to distinguish and are not very perfectly defined. Probably more than 60 species occur within the limits of this flora.]

VII. FRAGARIA L.

Perennial scape-bearing herbs, with runners. Leaves with 3 leaflets; stipules united to the petiole. Flowers (of American species) white. Calyx hypogynous, 5-parted, 5-bracted, persistent. Petals 5. Stamens many. Carpels many, on a convex receptacle. Akenes of the ripe strawberry many, very small, more or less imbedded in the large, sweet, pulpy receptacle.

1. **F. virginiana** Duchesne. WILD STRAWBERRY. Leaflets thick, oval to obovate, coarsely serrate, somewhat hairy. Scape usually shorter than the petioles, few-flowered. Fruit ovoid, akenes imbedded in deep pits. Common.*

2. F. vesca L. EUROPEAN STRAWBERRY. Leaflets ovate or broadly oval, dentate above, wedge-shaped below, slightly hairy. Scape usually longer than the petioles. Fruit globular or oval, akenes adherent to the nearly even surface of the receptacle. Common in cultivation. Many of the cultivated varieties of strawberry are hybrids between the two described above. The following variety is by some regarded as distinct.*

Var. **americana** Porter. AMERICAN WOOD STRAWBERRY. Slender, smooth or silky-downy. Leaflets very thin, sharply cut-toothed, downy beneath with close-lying silvery hairs, the down of the scapes, the pedicels, and sometimes of the leafstalks also, usually close-lying. Calyx lobes reflexed in fruit. Rocky woods.

VIII. WALDSTEINIA Willd.

Stemless perennial herbs. Leaves 3–5-lobed or -divided. Flowers several, rather small, yellow, on a bracted scape. Calyx tube top-shaped; the limb spreading, with sometimes little bracts alternating with the lobes. Petals 5. Stamens many. Style 2–6. Akenes few, on a dry receptacle.

1. W. fragarioides Tratt. BARREN STRAWBERRY. A low herb with much the appearance of a strawberry plant. Leaflets 3, broadly wedge-shaped, crenate-dentate. Scapes many-flowered; the flowers rather pretty. Wooded hillsides.

IX. POTENTILLA L.

Perennial herbs, rarely shrubs. Leaves compound; stipules united to the petiole. Flowers white or yellow, rarely red; solitary or in cymes. Calyx hypogynous, 5-cleft, with 5 little bracts alternating with its lobes. Petals 5. Stamens many. Carpels usually many, on a dry convex or concave receptacle; styles falling off from the akenes as they mature.

B. Fl. species 5 (*Argentina*).

1. P. arguta Pursh. UPRIGHT CINQUEFOIL. An erect, stout, hairy plant, 1–4 ft. high. Basal leaves long-petioled, pinnate. Stem leaves few, each of 3–7 leaflets, the latter broadly ovate and cut-toothed or serrate, downy underneath. Flowers large, in dense terminal clusters; the petals whitish or cream color. Rocky hills.

2. P. monspeliensis L. ROUGH CINQUEFOIL. Annual or biennial. Stem rough-hairy, erect and stout, 6–30 in. high. Leaves of 3 leaflets, the lower petioled, the upper stem leaves sessile or nearly so,

leaflets cut-serrate. Flowers small, in a close, leafy cyme. Styles glandular-thickened at the base. In dry soil.

3. P. rivalis Nutt., var. **millegrana.** DIFFUSE CINQUEFOIL. Annual. Stems decumbent or ascending, commonly diffusely branched, 1¼–3 ft. high, clothed with long, soft hairs or nearly smooth. Leaves all but the uppermost of 3 leaflets and petioled; leaflets oblong, wedge-shaped, thin, deeply serrate. Flowers yellow, in loose, leafy cymes. Style somewhat thickened below. In damp soil W.

4. P. argentea L. SILVERY CINQUEFOIL. Stems prostrate or ascending and branching, woolly. Leaflets oblong, wedge-shaped, those of the upper leaves very narrow, with a few large, deeply cut teeth, smooth and green above, silvery beneath, with a dense coat of white wool. Flowers small and somewhat clustered, yellow. Dry fields and roadsides.

5. P. Anserina L. SILVERWEED. Stems spreading by slender runners, with many joints, silky-hairy. Leaves all basal, pinnate; leaflets 7–21, serrate, oblanceolate or obovate, nearly smooth above, white and silky-downy beneath. Flowers yellow, ½–1 in. in diameter. Style thread-like. River banks, brackish marshes, and borders of lakes.

6. P. canadensis L. COMMON CINQUEFOIL. Stems slender, procumbent, silky-hairy, sending out long runners. Leaflets obovate, wedge-shaped, appearing like 5 from the divisions of the 2 lateral ones. Peduncles 1-flowered in the axils of the leaves. Flowers yellow. Common in dry pastures and a troublesome weed.

X. FILIPENDULA Hill. (ULMARIA)

Tall perennial herbs. Leaves pinnately divided, with stipules. Flowers small, bisexual, in panicled cymes. Calyx 5-lobed. Petals 5, with claws. Stamens many, hypogynous, borne on a flat or slightly hollowed receptacle. Pistils 5–15, distinct. Carpels when ripe 1–2-seeded, looking like follicles but not splitting open.

1. F. rubra Hill. QUEEN OF THE PRAIRIE. Smooth, branching, 2–8 ft. high. Leaves very large, of 3–7 pinnately arranged leaflets, often with smaller ones between, the lobes cut or toothed; terminal leaflet much larger, 7–9-parted. Flowers showy, pink, fragrant, about ⅓ in. in diameter. Meadows and prairies, especially in moist soil, sometimes cultivated.

2. F. Ulmaria Maxim. MEADOWSWEET. Stem 1–3 ft. high. Leaves lyrate, interruptedly pinnate, white-downy beneath. Flowers yellowish-white, small, fragrant, in a dense compound cyme. Pods spirally twisted. Cultivated from Europe and sometimes escaping.

XI. GEUM L.

Erect perennial herbs. Basal leaves crowded, pinnate, with a very large terminal leaflet. Flowers and fruit much as in *Potentilla*, but the akenes tailed with the remains of the styles. B. Fl. species 5 (*Sieversia*).

1. G. canadense Jacq. WHITE AVENS. Stem erect, branching above, smooth or finely downy, 18–24 in. high. Basal leaves pinnate, or the earliest simple and rounded, long-petioled, serrate or dentate; terminal lobe larger than the lateral lobes; stem leaves short-petioled, 2–5-lobed or -parted. Flowers on slender peduncles. Petals white, not longer than the sepals. Styles jointed near the middle, the lower portion persistent and hooked. Ovaries and receptacle hairy; head of fruit globose. Rich woods.*

2. G. virginianum L. Stem 2–3 ft. high, stout and bristly-hairy. Lower leaves and basal leaves pinnate, varying greatly; upper leaves mostly of 3 leaflets or 3-parted. Petals white or pale yellow, small, shorter than the calyx lobes. Heads of fruit large, on stout, hairy peduncles; the receptacle nearly or quite smooth. Borders of woods and damp thickets.

3. G. macrophyllum Willd. LARGE-LEAVED AVENS. Stem stout, erect, bristly-hairy, 1–3 ft. high. Basal leaves lyrate-pinnate, the terminal portion much the largest, kidney-shaped or heart-shaped; lateral leaflets 3–6, with smaller ones between. Flowers terminal, yellow. Style $\frac{1}{4}$–$\frac{1}{3}$ in. long, downy below. In low grounds.

4. G. rivale L. WATER AVENS, PURPLE AVENS, CHOCOLATE ROOT. Stem $1\frac{1}{2}$–2 ft. high, somewhat downy or hairy, simple or nearly so. Basal leaves lyrate and somewhat pinnate, with the divisions irregular; stem leaves few, of 3 leaflets or 3-lobed. Flowers rather large. Petals purplish-yellow, as long as the brownish-purple calyx lobes. Styles long, purplish; stigmas thread-like, feathered with soft hairs, especially in fruit. Wet meadows.

5. G. triflorum Pursh. LONG-PLUMED PURPLE AVENS. Softly downy, scapes 6–18 in. high. Basal leaves petioled, tufted, pinnate; the larger leaflets obovate or oval, cut-toothed, with many smaller ones between. Flowers 3–8, light purple. Styles $1\frac{1}{2}$–2 in. long. In dry or rocky soil.

XII. RUBUS L.

Mostly prickly shrubs, producing runners. Leaves alternate, simple or compound; stipules united to the petiole. Flowers in terminal and axillary clusters, rarely solitary, white (in one American species (No. 3) purple rose color). Calyx hypogynous,

with a broad tube; its lobes 5, persistent. Petals 5. Stamens many. Carpels many, distinct, on a convex receptacle. Fruit a cluster of little 1-seeded drupes on a dry or somewhat juicy receptacle.

A. Raspberries

Grains of the fruit, when ripe, usually falling off from the receptacle and leaving the latter with the calyx.

1. R. idæus L., var. **aculeatissimus**. Red Raspberry. Stems widely branching, biennial, not rooting at the tips, armed with weak bristles and with a few hooked prickles. Leaves petioled, of 3–5 ovate leaflets which are sharply serrate and sometimes lobed, downy beneath. Flowers in terminal and axillary racemes and panicles, pedicels drooping. Fruit hemispherical or conical, red, separating easily from the receptacle. Common on mountains and burned clearings, Iowa and N., and widely cultivated.*

2. R. occidentalis L. Black Raspberry. Stems long and slender, often recurved and rooting at the tips, armed with weak, hooked prickles. Leaves petioled, 3–5 ovate leaflets, coarsely serrate, white-downy below. Flowers white, in compact terminal corymbs. Pedicels erect or ascending. Fruit black, hemispherical, separating easily from the receptacle. Common on borders of woods, Missouri and N., widely cultivated.*

3. R. odoratus L. Flowering Raspberry (often wrongly called Mulberry). Stems shrubby, rather stout, 3–5 ft. high, not prickly; the young shoots, peduncles, and calyx covered with sticky glandular hairs. Leaves large, simple, 3–5-lobed. Flowers showy, rose-purple, 1–2 in. in diameter, on many-flowered peduncles. Fruit red, flattish, eatable. Rather common E. and N., and often cultivated.

4. R. triflorus Richards. Dwarf Raspberry (also wrongly known as Mulberry). A slender, trailing plant, almost entirely herbaceous, not prickly but sometimes bristly. Leaves compound, usually of 3 but sometimes of 5 thin, ovate-lanceolate, frequently unsymmetrical leaflets, which are coarsely doubly serrate and often cleft or lobed, with a shining upper surface. Flowers small, on 1–3-flowered peduncles. Fruit usually few-grained, rather dark red, eatable, the grains adhering somewhat to the receptacle. Common, especially N., in hilly woods, often forming a dense carpet in the partial shade of pines.

B. Blackberries

Grains of the ripe fruit falling from the calyx along with the soft, eatable receptacle.

5. R. allegheniensis Porter. High Blackberry. Stem shrubby, erect or bending, 3–7 ft. high, glandular-downy above and with stout,

straightish prickles below. Leaves petioled, of 3–7 ovate leaflets which are acute, irregularly serrate, soft-hairy beneath. Flowers racemed, the lower ones leafy-bracted. Petals white, obovate, much longer than the taper-pointed sepals. Fruit long, of small drupelets. Common in thickets.*

6. R. cuneifolius Pursh. SAND BLACKBERRY. Stem shrubby, erect or diffuse, 2–3 ft. high; prickles straight or recurved. Leaves petioled, 3–5-foliate; leaflets obovate, serrate towards the apex, wedge-shaped towards the base, rough above, white downy-woolly beneath. Racemes mainly terminal, few-flowered. Petals white, longer than the sepals. Fruit ovoid, black, smaller than the preceding. Common in old fields.*

7. R. hispidus L. RUNNING SWAMP BLACKBERRY. Stem trailing or prostrate, often several feet in length, armed with recurved prickles. Leaves petioled, mostly of 3 leaflets; leaflets obovate, obtuse, thick, dark green and shining above. Flowering branches commonly erect, few-flowered, flowers white. Fruit small, reddish, turning nearly black. In swamps and low ground.

8. R. villosus Ait. LOW BLACKBERRY, DEWBERRY. Stems shrubby, trailing widely, 3–10 ft. long, somewhat prickly. Leaflets usually 3, but sometimes 5 or 7, ovate, acute, sharply (and doubly) cut-serrate, thin. Racemes upright on the short branches, 1–3-flowered. Fruit roundish, of fewer and larger grains than No. 5, very sweet when fully ripe. Common N., in stony or gravelly fields.

XIII. ROSA L.

Erect running or climbing prickly shrubs. Leaves pinnate, leaflets serrate, stipules united to the petiole. Calyx tube urn-shaped, with a rather narrow mouth. Petals (in single roses) 5. Stamens many, inserted around the inside of the mouth of the calyx tube. Ovaries many, hairy, ripening into bony akenes, inclosed in the rather fleshy and sometimes eatable calyx tube.

1. R. pratincola Greene. Stems densely prickly, 1–2 ft. high. Stipules narrow, usually with glandular teeth or a fringe of glandular hairs toward the tip; leaflets 7–11, varying from elliptical to nearly obovate, obtuse at the tip, narrowed at the base, simply toothed or serrate, rather firm and distinctly veined. Flowers usually in corymbs; sepals lanceolate, taper-pointed. Fruit globose, smooth. Prairies, especially W.

2. R. blanda Ait. EARLY WILD ROSE. Stems 1–3 ft. high, usually without prickles; stipules broad. Flowers generally large, corymbed or solitary; sepals after flowering closing over the mouth of the calyx tube and persistent. Rocks and rocky shores.

3. R. Woodsii Lindl. Stems 3–36 in. high, with slender spines which are often wanting above. Stipules rather broad, entire; leaflets usually 5–7, varying from obovate to lanceolate, rather obtuse at the apex, narrowed at the base, somewhat serrate. Flowers corymbed or solitary. Sepals erect on the globose or somewhat ovoid fruit. Prairies W.

4. R. rubiginosa L. Sweetbrier. Stem erect or curving, armed with stout recurved prickles. Leaves with 5–7 leaflets, the latter broadly oval, coarsely serrate, glandular-bristly beneath, aromatic. Flowers white or pink. Sepals widely spreading, deciduous. Fruit obovate, slightly bristly. Common in cultivation and sometimes wild.*

5. R. carolina L. Swamp Rose. Stems 4–8 ft. high, with stout and generally recurved prickles. Stipules long and narrow; leaflets commonly downy beneath, finely serrate. Flowers several in a corymb, bright rose color. Sepals spreading and falling off after flowering. Damp woods and borders of swamps.

6. R. virginiana Mill. Dwarf Wild Rose. Stems varying in height from less than a foot to 6 ft., with stout, somewhat hooked prickles. Stipules rather broad; leaflets small, thickish and glossy above, coarsely toothed toward the tip. Flowers corymbed or solitary, pale rose color. Sepals spreading and falling off after flowering. Moist ground and swamps.

7. R. humilis Marsh. Pasture Rose. Stem erect, branched, usually armed with stout stipular prickles and with bristles, but sometimes nearly smooth, 1–3 ft. tall. Leaves mostly of 5 leaflets; stipules entire; leaflets oblong-lanceolate or oval, shining above, pale beneath, sharply serrate. Flowers solitary or 2–3 together, 2–3 in. broad, pink. Peduncles and calyx glandular-downy. Sepals leaf-like, spreading, finally deciduous. Styles distinct. Fruit globose, bristly-hairy. On dry soil; our most common wild rose. S.*

XIV. PRUNUS L.

Trees or shrubs. Leaves simple, with stipules, which are often small or fall off early. Calyx with a bell-shaped or urn-shaped tube and 5-lobed spreading limb, falling off after flowering. Petals 5; stamens 3–5 times as numerous, or indefinite, inserted on the throat of the calyx tube. Pistil 1, long-styled, with 2 ovules, ripening into a single drupe.

B. Fl. species 8 (*Amygdalus*).

A. *Stone more or less spherical; fruit smooth when ripe. Branches not spiny.* (*Cherries.*)

1. P. serotina Ehrh. Wild Black Cherry. Often becoming a large tree; bark on old trees rough, nearly black. Leaves rather

thick, oval to lanceolate-ovate, acute or taper-pointed at the apex, finely serrate with calloused teeth, smooth above, downy on the veins beneath. Racemes terminal, long and spreading. Flowers white. Fruit globose, about $\frac{1}{4}$ in. in diameter, purplish-black. In rich woods. Wood much used in cabinet-making.*

2. P. virginiana L. CHOKECHERRY. A shrub or small tree, 5–20 ft. high. Leaves thin, oval or obovate, pale, pointed, sharply serrate. Flowers small, white, in short racemes. Fruit bright red, turning at length to dark crimson, very puckery until fully ripe. River banks and thickets.

3. P. pennsylvanica L. f. WILD RED CHERRY. A tree 20–30 ft. high, with light, reddish-brown bark. Leaves oval or oblong-lanceolate, pointed, finely serrate, with both sides green, smooth and shining. Flowers long-pediceled, many in a cluster, the clusters lateral, leafless. Fruit globose, very small, light red, with thin sour pulp and globular stone. In rocky woods.

4. P. Besseyi Bailey. WESTERN SAND CHERRY. A shrub 1–4 ft. high, often with spreading and prostrate branches. Leaves usually elliptic or oblong-elliptic, with appressed teeth. Flowers sessile in lateral umbels, $\frac{1}{3}$ in. to nearly $\frac{1}{2}$ in. in diameter, opening with the leaves. Fruit black, mottled, or yellowish, $\frac{1}{2}$–$\frac{2}{3}$ in. in diameter, bitter and astringent. Prairies W.

5. P. Cerasus L. CHERRY. Often becoming a large tree. Leaves oval or ovate, acute or taper-pointed at the apex, rounded at the base, irregularly serrate-dentate, smooth on both sides, resinous when young. Flowers in lateral umbels, white; pedicels long and slender. Fruit globose, red or black. Cultivated from Europe. This is the species from which most of our sour cultivated varieties have been developed.*

B. *Stone oval, compressed; fruit smooth when ripe. Branches often spiny.* (*Plums.*)

6. P. angustifolia Marsh. CHICKASAW PLUM. A small tree with spiny branches. Leaves lanceolate or oblong-lanceolate, acute at the apex, usually obtuse at the base, finely and sharply serrate, rather thin, smooth. Flowers in lateral, sessile umbels, pedicels short. Calyx smooth. Fruit yellowish-red, subglobose, skin thin, stone only slightly compressed. In old fields S.*

7. P. americana Marsh. WILD PLUM. A small tree, bark thick and rough, branches spiny. Leaves ovate or obovate, acuminate at the apex, rounded or cordate at the base, sharply serrate, rather thick, downy beneath; petioles glandular. Flowers in lateral, sessile umbels, appearing with or before the leaves; pedicels $\frac{1}{2}$–$\frac{3}{4}$ in. long, flowers $\frac{1}{2}$–$\frac{3}{4}$ in. in diameter. Calyx downy within. Fruit globose, red or yellow, $\frac{1}{2}$–1 in. in diameter. Common in woods.*

C. *Stone deeply furrowed and pitted; fruit downy when ripe. Branches not spiny.* (*Peaches and almonds.*)

8. P. persica Stokes. PEACH. A tree with a rounded top; bark nearly smooth. Leaves lanceolate, taper-pointed, finely serrate, smooth on both sides; petioles usually bearing 2 or 4 crescent-shaped or cup-shaped glands. Flowers pink, scaly-bracted. Fruit ovoid, with a seam along one side. Often escaped from cultivation.*

47. LEGUMINOSÆ. PULSE FAMILY

Herbs, shrubs, or trees. Leaves alternate, usually compound (either pinnately or palmately), with stipules, the leaflets mostly entire. Calyx of 5 sepals, which are more or less united, often somewhat zygomorphic. Corolla of 5 petals,

FIG. 20. Pulse Family

A, actinomorphic corolla (*Acacia cinerascens*); *B*, zygomorphic corolla (*Cassia marilandica*). (After Schnizlein)

often papilionaceous (Fig. 21) or somewhat actinomorphic, in No. XVI much reduced. Stamens diadelphous (Fig. 22), monadelphous, or distinct. Ovary simple, superior. Fruit usually a 1-celled pod (Fig. 22). Seeds one or several, without endosperm. A large and very important family, containing about 8000 species.

A

Flower actinomorphic, small. Stamens hypogynous. Leaves twice pinnate.

Petals not united to each other. Stamens 5 or 10. Pod smooth. Desmanthus, I

Corolla gamopetalous, 5-cleft. Stamens 8 or 10. Pod minutely prickly or rough. Schrankia, II

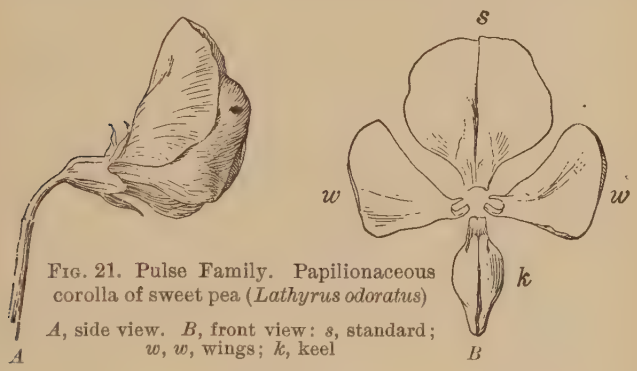


Fig. 21. Pulse Family. Papilionaceous corolla of sweet pea (*Lathyrus odoratus*)

A, side view. *B*, front view: *s*, standard; *w*, *w*, wings; *k*, keel

B

Trees. Flowers somewhat or not at all papilionaceous, sometimes almost actinomorphic. The upper petal inside the others in the bud. Stamens 10 or less, usually not united to each other, borne on the calyx.

Flowers imperfectly papilionaceous. Leaves simple. Cercis, V

Flowers not papilionaceous. Thornless. Gymnocladus, III

Flowers not papilionaceous. Thorny. Gleditsia, IV

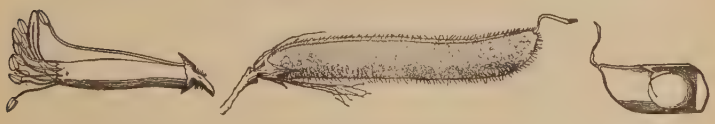


Fig. 22

A, stamens and pistil of sweet pea (magnified); *B*, fruit; *C*, part of fruit, showing one seed

C

Herbs or trees. Flowers decidedly papilionaceous. The upper petal external in bud and inclosing the others. Stamens 10, not united to each other.

Trees.	Cladrastis, VII
Herbs. Pod inflated.	Baptisia, VI
Herbs. Pod elongated, necklace-shaped.	Sophora, VIII

D

Shrubs with a corolla of one petal only.	Amorpha, XVI

E

Herbs, shrubs, or trees. Flowers decidedly papilionaceous. Stamens monadelphous or diadelphous (in the latter case usually 9 and 1).

1. Stamens with anthers of two forms.
   - (*a*) Herbs. Leaves usually with many leaflets. Lupinus, IX
   - (*b*) Herbs. Leaves with 3 entire leaflets. Psoralea, XV
   - (*c*) Trees. Laburnum, X
   - (*d*) Low shrubs. Cytisus, XI
2. Anthers all alike. Leaves usually with 3 leaflets.
   - (*a*) Pod coiled. Medicago, XIV
   - (*b*) Pod small, not coiled. Flowers in racemes. Melilotus, XIII
   - (*c*) Pod small, not coiled. Flowers in heads. Trifolium, XII
   - (*d*) Pod large, flattened, bur-like. Desmodium, XX
   - (*e*) Pod large, not much flattened. Phaseolus, XXIV
3. Anthers all alike. Leaves odd-pinnate, with more than 3 leaflets.
   - (*a*) Low, woody shrubs. Amorpha, XVI
   - (*b*) Tall, twining shrubs. Wisteria, XVIII
   - (*c*) Trees. Robinia, XVII
   - (*d*) Herbs. Astragalus, XIX
4. Anthers all alike. Leaves pinnate, the midrib prolonged into a tendril.

(*a*) Leaflets usually many pairs. Style slender, bearded only at the tip or all round the upper portion. Pod 2–several-seeded. Vicia, XXI

(*b*) Leaflets few or several pairs. Style bearded along one face only. Pod several-seeded. Lathyrus, XXII

(*c*) Leaflets 1–3 pairs. Style enlarged above, grooved on the back. Pod several-seeded; seeds large, globular or nearly so. Pisum, XXIII

I. DESMANTHUS Willd. (ACUAN)

Shrubs or perennial herbs. Stems erect or diffuse, smooth. Leaves abruptly twice-pinnate; stipules small. Flowers in heads or spikes, on axillary peduncles, the upper bisexual, the lower often staminate or neutral. Calyx 5-toothed. Corolla of 5 distinct petals or 5-cleft. Stamens 5–10, distinct. Ovary nearly sessile, flat, several-seeded.*

1. D. illinoensis Mac M. DESMANTHUS. Stem erect or ascending, smooth, 1–4 ft. high. Pinnæ 6–14 pairs, each with a minute gland at the base; leaflets 20–30 pairs, small, linear. Heads globose. Stamens 5. Pods several, on a peduncle 2–3 in. long, curved, flat, 2-valved, 3–6-seeded. Open, sandy fields.*

II. SCHRANKIA Willd. (MORONGIA)

Perennial herbs. Stems reclining or prostrate, prickly, 2–5 ft. long. Leaves twice-pinnate; stipules bristly. Flowers bisexual or somewhat monœcious, in axillary peduncled heads. Calyx minute. Corolla tubular, 5-cleft. Stamens 8–10, distinct. Pod long, prickly, 1-celled.*

1. S. uncinata Willd. SENSITIVE BRIER, SENSITIVE ROSE, SHAME VINE. Plant covered with hooked prickles. Leaflets elliptical, with a conspicuous network of veins beneath; leaves closing gradually after being touched. Flowers rose-colored. Pods nearly cylindrical, 2 in. long. Dry, sandy soil and rolling prairies, especially S. and W.

III. GYMNOCLADUS Lam.

A large, thornless tree, its twigs few and stout. Leaves very large, twice pinnately compound, without stipules. Flowers actinomorphic, whitish, dicœcious or somewhat monœcious, in

racemes at the ends of the branches. Calyx tube rather long, its 5 lobes spreading. Petals oblong, all alike, inserted with the stamens on the throat of the calyx. Stamens of the fertile flowers usually not pollen-bearing. Pod hard, flat, partly filled with a sweet substance, slow in opening. Seeds several, flattish, over ½ in. in diameter, very hard and shining.

1. G. dioica Koch. Kentucky Coffee Tree. Tree 50 ft. or more in height, with rough gray bark. Leaves 2–3 ft. long, the leaflets vertical. Pods sometimes nearly 1 ft. long. Rich soil and river bottoms, especially S. and W.

IV. GLEDITSIA L.

Large trees; bark dark-colored, nearly smooth. Leaves usually pinnately twice compound; leaflets serrate. Flowers somewhat monœcious, in small spike-like racemes. Calyx spreading, 3–5-cleft. Petals as many as the sepals and inserted at the summit of the tube. Stamens 5 10, distinct, inserted with the petals. Ovary nearly sessile, ovoid or elongated. Fruit a 1-or many-seeded, leathery pod.*

1. G. triacanthos L. Honey Locust. A large tree, usually armed with stout, branched thorns, which are sometimes a foot or more in length. Leaves petioled; leaflets short-stalked, lanceolate-oblong, base inequilateral, smooth above, often downy below. Racemes solitary or in small clusters, drooping. Flowers inconspicuous, greenish. Pod linear-oblong, often 12–15 in. long by 1 in. wide, twisted, many-seeded, smooth and shiny, pulpy within. In rich woods.

V. CERCIS L.

Trees. Leaves simple, with stipules. Flowers in axillary clusters, somewhat papilionaceous. Calyx bell-shaped, 5-toothed. Stamens 10, distinct. Ovary short-stalked; ovules several. Fruit a flattened pod.

1. C. canadensis L. Redbud. A small tree, 10–20 ft. high; wood hard but weak; bark smooth, dark-colored. Leaves broadly cordate, abruptly acute, rather thick, very smooth above, often slightly downy below. Flowers several in a cluster, appearing before the leaves, pinkish-purple. Pod oblong, compressed, many-seeded. Common on rich soil, especially S.*

VI. BAPTISIA Vent.

Perennial herbs; stems erect, widely branched. Leaves simple or palmate, of 3 leaflets. Flowers in racemes. Calyx 4–5-lobed, persistent, the upper lobe usually longer and notched; standard rounded, its sides reflexed, wings about as long as the keel. Stamens 10, distinct. Pod stalked, long-pointed by the remains of the style. Plants usually becoming black in drying.*

1. B. tinctoria R. Br. Wild Indigo. Stem smooth, slender, 2–4 ft. high; branches slender. Leaves of 3 leaflets, on short petioles, the upper nearly sessile; stipules minute, quickly deciduous. Leaflets obovate to oblanceolate, obtuse at the apex, wedge-shaped at the base, entire. Racemes numerous, terminal. Flowers yellow, ½ in. long. Pod globose, ovoid, on a stalk about the length of the calyx, point long and slender. Plant blackening in drying. Common on dry, sandy soil.*

2. B. bracteata Muhl. Low, hairy, and branching. Leaves nearly sessile; leaflets oblanceolate or obovate-spatulate; stipules triangular-ovate, large, persistent; bracts large and leaf-like. Racemes long. Flowers large, yellowish-white. Pod ovoid, swollen. Prairies and open woods W. and S.

3. B. leucantha T. & G. Stout, smooth, and covered with a bloom, 3 ft. or more high, with spreading branches. Petioles short; lanceolate stipules and bracts falling off early. Racemes erect. Flowers large, white. Pods ellipsoidal, 2 in. long, borne on a stalk twice as long as the calyx. Rich river bottoms and prairies.

4. B. alba R. Br. White Wild Indigo. Stem smooth and with a bloom, often purple, 2–3 ft. high; branches slender, spreading. Leaves petioled, with 3 leaflets; stipules minute, soon deciduous. Flowers white, mostly in a single raceme which is 1–3 ft. long, with occasionally lateral, few-flowered racemes. Pod linear-oblong, the point very slender and soon deciduous. Plant unchanged in drying. In damp soil.*

5. B. australis R. Br. Blue False Indigo. Stem smooth, stout, 2–4 ft. high. Leaves of 3 leaflets, short-petioled; stipules lanceolate, persistent, longer than the petioles; leaflets oblong, wedge-shaped or narrowly obovate, entire. Flowers bright blue, 1 in. long, in terminal, erect, loosely flowered racemes; stalk about the length of the calyx. Pod oblong, with a slender, persistent point. Banks of rivers; often cultivated for ornament.*

VII. CLADRASTIS Raf.

A moderate-sized tree, with smooth dark gray bark and yellow wood. Leaves of 7–11 smooth oval or ovate leaflets.

Flowers creamy-white, in long, drooping panicles. Calyx 5-toothed. Standard large, nearly round, reflexed; petals of the keel and wings separate and straight. Stamens 10, unconnected with each other. Pod borne on a short stalk above the calyx. Seeds 4–6.

1. C. lutea Koch. YELLOW WOOD. Tree 50 ft. or less in height, much branched, with a round, spreading top. Hillsides, in fertile soil, south central states. Also considerably planted as a shade tree.

VIII. SOPHORA L.

Shrubby or herbaceous perennials. Leaves odd-pinnate, with many leaflets. Calyx bell-shaped, with 5 short teeth. Standard roundish; keel nearly straight. Stamens almost or quite distinct; anthers versatile. Pod stalked, leathery or fleshy, nearly cylindrical but more or less contracted between the seeds, not splitting open.

1. S. sericea Nutt. Herbaceous with a woody base, erect, 6–12 in. high, covered with silky silvery down. Leaflets 7–25, obovate or nearly so, obtuse, narrowed at the base, $\frac{1}{4}$–$\frac{1}{2}$ in. long. Flowers white. Pod slender, dry, few-seeded. Prairies W. and S.W.

IX. LUPINUS L.

Biennial or perennial herbs. Leaves simple or palmately compound. Flowers showy, in terminal racemes. Calyx 2-lipped, 5-toothed. Standard round, with the sides reflexed; keel scythe-shaped. Stamens monadelphous; anthers alternately oblong and roundish. Ovary sessile; matured pod oblong, several-seeded, often compressed between the seeds.*

1. L. perennis L. Perennial. Stem erect, downy, 12–18 in. high. Leaves palmately 7–9-foliate; leaflets obovate or oblanceolate, obtuse and mucronate at the apex, slightly downy; petiole slender; stipules small. Racemes terminal, slender, loosely many-flowered. Flowers purple, blue, pink, or white. Pod oblong, densely downy, few-seeded. Dry, sandy soil.*

X. LABURNUM Medic.

Trees or shrubs. Leaves of 3 leaflets, with very small stipules or none. Flowers golden-yellow, in slender, drooping racemes. Calyx 2-lipped, the upper lip 2-toothed, the lower 3-toothed. Standard ovate, upright, of the same length as the

straight wings. Stamens diadelphous (9 and 1). Ovary and pod somewhat stalked above the calyx, several-seeded.

1. L. vulgare Griseb. LABURNUM, GOLDEN CHAIN. A small tree, with smooth, greenish bark. Leaves with slender petioles; leaflets oblong-ovate, acute at the base, taper-pointed, downy beneath. Flowers showy, in graceful racemes. Cultivated from Europe.

XI. CYTISUS L.

Shrubs, rarely spiny. Leaves of 1–3 leaflets or none; stipules very small. Calyx 2-lipped, the upper lip slightly 2-toothed, the lower 3-toothed. Keel straight or a little curved, blunt, turned down after flowering. Stamens with their filaments all united; anthers every other one short and attached by its center, the alternate ones long and fastened by their bases. Style curved in, or, after the flower opens, coiled up. Pod flat, long, many-seeded.

1. C. canariensis Dumont. A shrub with many rather stiff, erect, slender branches. Leaves abundant, very small, covered with soft gray hairs; leaflets 3, obovate. Flowers rather small, yellow, in somewhat erect racemes. Cultivated in greenhouses. From the Canary Islands.

XII. TRIFOLIUM L.

Annual, biennial, or perennial herbs. Stems more or less spreading. Leaves petioled, of 3 toothed or serrate leaflets; stipules united to the petioles. Flowers white, yellow, or red, in heads. Calyx 5-cleft, the teeth nearly equal, awl-shaped. Petals withering-persistent; keel shorter than the wings. Stamens diadelphous. Pod smooth, 1–6-seeded, scarcely opening.*

1. T. arvense L. RABBIT FOOT CLOVER, STONE CLOVER. Annual, silky-downy, erect, branching, 5–10 in. high. Leaflets oblanceolate or linear, minutely toothed above. Heads terminal, peduncled. Calyx teeth very silky-hairy, longer than the whitish corolla. Old fields, railroad embankments, and waste ground. Naturalized from Europe.

2. T. incarnatum L. CRIMSON CLOVER. Annual. Stem erect, somewhat branched, downy, 1–2 ft. high. Lower leaves long-petioled, the upper short-petioled; leaflets obovate or wedge-shaped, toothed at the apex. Flowers bright crimson, sessile, in terminal heads which finally become much elongated. Calyx silky, its lobes long and plumose. Introduced from Europe and cultivated for fodder.

3. T. pratense L. Red Clover. Biennial or short-lived perennial. Stems spreading, branching, downy, 1–3 ft. long. Leaves long-petioled; stipules large; leaflets oval to obovate, finely toothed, often with a dark triangular spot near the center. Flowers red or purple, in globose heads, erect in fruit. Calyx teeth bristle-shaped, hairy. Pod 1–3-seeded. Introduced from Europe and widely cultivated.*

4. T. repens L. White Clover. Perennial. Stems widely branching at the base, prostrate and creeping, nearly smooth, 6–12 in. long. Leaves long-petioled; leaflets oval, obovate, or obcordate, minutely toothed. Heads globose, long-peduncled. Flowers white, reflexed in fruit. Pod 3–4-seeded. Common about houses and in pastures.*

5. T. hybridum L. Alsike Clover. Perennial, considerably resembling No. 4, but the stems more upright and stouter. Leaflets varying from broadly ovate to ovate-lanceolate, mucronate or slightly notched, the margins fringed with hairs; stipules prolonged into bristle-like points. Flowers rose color and white, very fragrant. In fields and along roadsides. Introduced from Europe.

6. T. carolinianum Michx. Carolina Clover. Perennial. Stems spreading or ascending, much-branched, downy, 6–10 in. long. Leaves short-petioled; leaflets small, obovate or obcordate, slightly toothed. Heads small, globose, on long peduncles. Flowers white, tinged with purple, reflexed in fruit. Pod 4-seeded. Common in waste places S.*

7. T. procumbens L. Low Hop Clover. Annual. Stem slender, erect or spreading, downy, 6–10 in. long. Leaves short-petioled; leaflets obovate or obcordate, finely dentate, the middle one distinctly stalked; stipules lance-ovate. Flowers yellow, reflexed in fruit. Pod 1-seeded. Common on clay soil, in waste places. Naturalized from Europe.*

XIII. MELILOTUS Hill.

Annual or biennial herbs. Leaves petioled, of 3 leaflets. Flowers small, white or yellow, in dense axillary and terminal racemes. Calyx 5-toothed, the teeth nearly equal. Standard erect, wings and keel cohering. Stamens 10, diadelphous. Pod longer than the calyx, 1–4-seeded.*

1. M. alba Lam. Melilotus. Biennial. Stem erect, branching, smooth or the young branches slightly downy. Leaflets oblong or oblanceolate, rounded or truncate at the apex, serrate; stipules small. Racemes long, slender, erect. Flowers white. Standard longer than the wings and keel. Pod ovoid, wrinkled, drooping, mostly 1-seeded, scarcely opening. Common as a weed and widely cultivated.*

2. M. officinalis Willd. Yellow Sweet Clover. A stout, upright, branching herb, 2–4 ft. high, looking much like the preceding species, but coarser. Flowers yellow. Waste ground and roadsides. Naturalized from Europe.

XIV. MEDICAGO L.

Annual or perennial herbs. Leaves petioled, of 3 toothed leaflets. Flowers in terminal and axillary spikes or racemes. Calyx 5-toothed, the teeth short and slender. Standard oblong, much longer than the wings or keel. Stamens 10, diadelphous. Ovary sessile. Pod 1–several-seeded, coiled, not splitting open, often spiny.*

1. M. sativa L. Alfalfa. Perennial. Stems erect, branching, downy when young, becoming smooth with age, 2–3 ft. high. Leaves short-petioled; leaflets obovate, sharply dentate towards the apex, obtuse or sometimes notched or mucronate; stipules lanceolate, entire. Flowers blue, small, in rather close spikes. Pods downy, coiled, few-seeded. Introduced from Europe, and cultivated for hay and pasture.*

2. M. lupulina L. Black Medick, Nonesuch. An annual or biennial, much-branched, reclining herb, with stems 6–20 in. long. Leaves very short-petioled; leaflets obovate, acute, $\frac{1}{4}$–$\frac{3}{4}$ in. long, toothed near the tip. Flowers small, yellow, in short spikes. Pods very small, 1-seeded, kidney-shaped, black. Roadsides and waste ground, adventive from Europe.

XV. PSORALEA L.

Perennial herbs; whole plant glandular-dotted. Leaves of 3–5 leaflets; stipules united with the petioles. Flowers in axillary or terminal spikes or racemes. Calyx 5-cleft, the lobes nearly equal. Standard ovate or orbicular; keel incurved, obtuse. Stamens monadelphous or diadelphous, 5 of the anthers often undeveloped. Ovary nearly sessile. Pod included in the calyx, often wrinkled, remaining closed, 1-seeded.*

1. P. pedunculata Vail. Samson's Snakeroot. Stem erect, slender, branching above, downy, 1–2 ft. high. Leaves of 3 leaflets; petioles shorter than the leaflets; stipules awl-shaped; leaflets elliptical or oblong-lanceolate, sparingly glandular-dotted, the terminal one stalked. Loosely flowered spikes axillary and terminal, on peduncles much longer than the leaves. Flowers blue or purple, about $\frac{1}{3}$ in. long. Pod compressed-globose, wrinkled transversely. Dry soil.*

2. P. tenuiflora Pursh. Upright, slender, bushy and branching, 2–4 ft. high, covered when young with a fine grayish down. Leaves

palmately compound, with 3–5 linear to obovate-oblong leaflets, covered with glandular dots. Flowers $\frac{1}{6}$–$\frac{1}{4}$ in. long, loosely racemed. Pod rough with glands. Prairies W.

3. P. argophylla Pursh. Silver-Leaved Psoralea. Densely silvery downy, with white, close-lying hairs. Stem often zigzag, 1–3 ft. high. Leaves palmate; leaflets 3–5, elliptical-lanceolate, oval or obovate. Spikes interrupted, the peduncles longer than the leaves. Flowers blue or purplish, $\frac{1}{3}$ in. or more long. Pod ovate, beak straight. Prairies, especially N.W.

4. P. esculenta Pursh. Pomme Blanche, Tipsin, Dakota Turnip. Clothed with roughish hairs. Stem 5–15 in. high, erect and stout. Root turnip-shaped, starchy, eatable. Leaves palmately compound, with 5 lance-oblong leaflets. Flowers $\frac{1}{2}$ in. long, in a dense ellipsoidal spike. Pod hairy, with a pointed tip. High prairies or plains, especially N.W.

XVI. AMORPHA L.

Small shrubs, glandular-dotted. Leaves odd-pinnate. Flowers purple, blue, or white, in slender spikes or racemes. Calyx 5-toothed, persistent. Standard obovate, concave; wings and keel none. Stamens monadelphous, projecting much. Ovary sessile. Pod curved, glandular-roughened, 1–2-seeded, never opening.*

1. A. canescens Pursh. Lead Plant, Shoe Strings. A bushy, white, silky-downy shrub, 1–3 ft. high. Leaflets small and crowded, 21–49, oval or oblong-elliptical. Spikes mostly clustered at the summit, rather showy. Standard bright blue, roundish. Pod 1-seeded, slightly longer than the calyx. Prairies. Roots very long and tough, hence one common name.

2. A. microphylla Pursh. A bushy shrub about 1 ft. high. Leaves many, short-petioled; leaflets 13–19, rigid, oval or oblong. Racemes mostly solitary. Flowers fragrant; standard purplish. Prairies, especially N.W.

3. A. fruticosa L. False Indigo. A shrub, 6–15 ft. high, with smooth, dark-brown bark. Leaves petioled; leaflets 15–21, short-stalked, oblong, obtuse or notched, sparingly punctate with clear dots. Slender flowering spikes, panicled or solitary, 4–6 in. long. Flowers blue or purple. Calyx teeth short, nearly equal, downy. Pod glandular. River banks.*

XVII. ROBINIA L.

Trees or shrubs. Leaves odd-pinnate; stipules often spiny. Flowers showy, in axillary racemes. Calyx short, 5-toothed,

the two upper teeth shorter and partially united. Standard large, orbicular, reflexed, keel obtuse. Stamens diadelphous. Style bearded on one side. Pod compressed, several-seeded.*

1. R. Pseudo-Acacia L. BLACK LOCUST. A tree of medium size; bark rough and nearly black; twigs and leaves smooth. Leaflets 9–15, ovate or oblong, obtuse and slightly mucronate at the apex; stipules forming persistent spines. Racemes loose, pendulous, 3–5 in. long. Flowers white, fragrant. Pod smooth, 4–8-seeded. Introduced, and quite common; wood very durable when exposed to the weather, and extensively used for posts.*

XVIII. WISTERIA Nutt. (BRADLEYA)

Tall, twining shrubs. Leaves odd-pinnate. Racemes terminal. Flowers large and showy. Calyx 2-lipped, the upper lip 2-cleft, short, the lower longer and 3-cleft. Standard large, round, with 2 calloused ridges at the base; wings eared at the base; keel scythe-shaped. Pod long, stalked, leathery, 2-valved, several-seeded.*

1 W. frutescens Poir. WISTERIA. Stem climbing 30–40 ft., often 2–3 in. in diameter at the base; branches and leaves downy when young, becoming smoother with age. Leaves short-petioled; stipules minute; leaflets 9–17, ovate-lanceolate, acute at the apex, rounded at the base. Racemes large, densely flowered. Calyx downy. Corolla lilac-purple, wings with a short and a long appendage at the base. Pod 2–3 in. long, 2–4-seeded. River banks S. Often cultivated for ornament.*

2. W. chinensis DC. CHINESE WISTERIA. Larger and faster growing than No. 1. Racemes longer and more slender. Wing appendage at one side only of base. Seldom fruiting in this region. Cultivated from China or Japan.

XIX. ASTRAGALUS L.

Mostly perennial herbs. Leaves odd-pinnate. Flowers in spikes or racemes. Calyx 5-toothed. Petals long, erect, with claws. Standard narrow. Stamens diadelphous (9 and 1). Pod usually swollen, sometimes fleshy and eatable, several–many-seeded. [A large and very difficult genus; mostly of far western species.]

1. **A. caryocarpus** Ker. Ground Plum, Buffalo Apple. Covered with pale, close-lying down. Leaflets narrow, oblong. Flowers violet-purple, in a short, narrow raceme. Fruit looking like a small, green, pointed plum, about $\frac{2}{3}$ in. in diameter, eatable. N.W., and S. to Texas.

2. **A. mexicanus** A. DC. Prairie Apple. Smooth or with some loose hairs. Corolla cream color, with the tip bluish. Fruit globular, not pointed, eatable. Prairies, Illinois and S.W.

3. **A. canadensis** L. Erect, often tall (1–4 ft. high), more or less downy. Leaflets oblong, 21–27. Flowers pale greenish, in long spikes. Pod dry, 2-celled, sessile. River bottoms, prairies, and woods.

4. **A. parviflorus** MacM. Erect and slender, finely downy, somewhat ash-color, 1–2 ft. high. Leaflets 11–21, linear, obtuse, distant. Flowers purple, $\frac{1}{4}$–$\frac{1}{3}$ in. long, in long, slender racemes. Pods sessile, $\frac{1}{4}$ in. or less in length, concave on the back, white-hairy, becoming smooth. Prairies, especially N.W.

XX. DESMODIUM Desv. (MEIBOMIA)

Perennial herbs. Leaves pinnate, with stipules, usually with 3 leaflets. Flowers in axillary or terminal racemes, or sometimes in panicles, usually purple, sometimes pink or whitish. Calyx usually somewhat 2-lipped. Standard ovate, obovate, or roundish; wings attached to the straight or nearly straight keel by a little appendage projecting from each side of the keel. Stamens monadelphous (9 and 1) or all united at their bases. Pod flat, its lower margin variously lobed, separating into flat segments which are usually furnished with short, strong, hooked hairs, making the fruit a troublesome bur. [A large and rather difficult genus. Most of the species can only be distinguished by the fruit, which matures in late summer or autumn.]

XXI. VICIA L.

Climbing or spreading herbs. Leaves odd-pinnate, usually ending in a tendril. Leaflets many, entire or toothed at the tip; stipules half arrow-shaped. Flowers blue, purple, or yellow, in axillary racemes. Calyx teeth nearly equal. Wings united to the keel. Stamens diadelphous (9 and 1); filaments thread-shaped; anthers all alike. Style bent, smooth or downy all round or bearded below the stigma; ovules usually many. Pod flattened, 2–several-seeded. Seeds globular.

1. V. sativa L. Common Vetch. Annual. Stem simple, smooth, reclining, 1–3 ft. long. Leaves short-petioled; leaflets 2–5 pairs, obovate-oblong to linear, obtuse, notched and mucronate at the apex. Flowers in pairs, nearly sessile in the axils, pale purple, ¾ in. or less in length. Pod linear, several-seeded. In gravelly soil. Introduced from Europe.

2. V. caroliniana Walt. Perennial. Smooth or nearly so, 4–6 ft. high. Leaflets 8–24, narrowly oblong, blunt. Peduncles loosely flowered. Flowers small, whitish or tipped with pale purple. River banks.

3. V. americana Muhl. Wild Vetch, Buffalo Pea. Perennial. Smooth, 1–3 ft. high. Leaflets 10–14, elliptical or ovate-oblong, obtuse. Peduncles shorter than the leaves, 4–8-flowered. Flowers bluish-purple, ¾ in. long. Common N. and W.

XXII. LATHYRUS L.

Like *Vicia*, excepting that the leaflets are fewer and the style is bearded on the side toward the standard.

1. L. maritimus Bigelow. Beach Pea. Perennial. Stem stout, 1–2 ft. high. Stipules broadly ovate and heart- or halberd-shaped, nearly as large as the 6–12 leaflets, of which the lower pair is the largest; tendrils pretty large. Flowers large, blue or purple. Seashores and beaches of the Great Lakes.

2. L. palustris L. Wild Pea. Stem frequently winged, slender, and climbing by delicate tendrils at the ends of the leaves. Stipules narrow and pointed; leaflets 4–8, narrowly oblong to linear, acute. Peduncles bearing 2–6 pretty large, drooping, blue, purple, and white flowers. Damp thickets and borders of swamps.

3. L. venosus Muhl. Veiny Vetch. Perennial. Stem stout, prominently angled, climbing or reclining, 2–5 ft. long. Leaves short-petioled; stipules large, lanceolate; leaflets 5–7 pairs, broadly ovate-obtuse, mucronate. Peduncles nearly as long as the leaves, many-flowered. Flowers purple, ¾ in. long. Calyx teeth very unequal. Pod linear, veined, 4–6-seeded. Shady banks and moist prairies.*

4. L. odoratus L. Sweet Pea. Annual. Stem roughish-hairy, it and the petioles winged. Leaflets only one pair, oval or oblong. Flowers large, 2 or 3 on the long peduncles, sweet-scented, white, rose color, purple, or variegated. Cultivated from Europe.

XXIII. PISUM L.

Climbing or prostrate herbs. Style enlarged above, grooved on the back, with soft-hairy down on the inner edge. Leaflets 1–3 pairs. Flowers and fruit much like those of *Lathyrus*.

1. P. sativum L. Common Pea. Annual. Smooth and covered with a bloom. Leaflets usually 2 pairs; tendrils branching; stipules large, ovate, rather heart-shaped at the base. Peduncle several-flowered. Flowers white, bluish, reddish, or variegated. Pods large; seeds globular or somewhat flattened and wrinkled. There are many varieties, differing greatly in size, of the plant and of the fruit. Cultivated from Europe (?).

XXIV. PHASEOLUS L.

Twining herbs. Leaves pinnate, of 3 leaflets. Flowers in axillary racemes. Calyx 5-toothed or 5-cleft, the two upper teeth often more united than the others. Keel of the corolla coiled in a spiral, together with the included stamens and style. Stamens diadelphous (9 and 1). Style bearded lengthwise on the upper side; stigma oblique or on the side of the style. Pod linear, 2-valved, several–many-seeded, tipped with the remains of the style.

1. P. perennis Walt. Wild Bean. Perennial, climbing high. Flowers small, purple. Pods curved, drooping, 4–6-seeded. Thickets.

2. P. vulgaris L. Common or Kidney Bean. Twiners (or some varieties low and branching). Racemes of white or purplish flowers shorter than the leaves. Pods straight or nearly so. Seeds not much flattened. Cultivated, probably from tropical America.

3. P. multiflorus Willd. Spanish Bean, Scarlet Runner. Stems twining high. Flowers large and showy, white, scarlet, or variegated; racemes longer than the leaves. The scarlet variety is the most commonly cultivated, for ornament. From tropical America.

48. GERANIACEÆ. Geranium Family

Herbs or small shrubs. Leaves simple, usually with glandular hairs which secrete an aromatic oil. Flowers bisexual, axillary and solitary or clustered, actinomorphic or nearly so, hypogynous, their parts in fives. Stamens 5 or 10, monadelphous at the base. Carpels 5, each 2-ovuled, splitting away with their long styles when ripe from a central axis and thus scattering the seeds.

I. GERANIUM L.

Herbs, rarely shrubs. Leaves with stipules, opposite or alternate, usually cut or lobed. Flowers actinomorphic on

1–2-flowered axillary peduncles. Sepals and petals 5. Stamens 10, ripening in 2 sets. Ovary 5-lobed, 5-beaked; stigmas 5.

1. G. maculatum L. Wild Crane's-Bill, Wild Geranium. Perennial, with an erect, hairy stem, 12–18 in. high. Leaves about 5-parted, marked with pale blotches, the basal leaves long-petioled. Flowers large (1 in. or more in diameter), light purple, somewhat corymbed. Petals entire, twice as long as the calyx, the claw bearded. Open woods and thickets; common.

2. G. Robertianum L. Herb Robert. Annual or biennial. Stems somewhat hairy, weak and spreading, reddish. Leaves of 5 leaflets, the latter once or twice pinnately cut, long-petioled. Flowers light purple, about ½ in. in diameter, streaked with dark and light red. Claws of petals smooth. Damp woods and ravines E.

II. PELARGONIUM L'Her.

Perennial herbs or shrubs. Leaves with stipules, scented. Flowers much as in the preceding genus, but one of the sepals hollowed out below into a nectar-bearing tube extending down the pedicel. The 2 upper petals different in size or shape from the other 3. Cultivated from the Cape of Good Hope. [Most of the species are commonly, though not quite correctly, called "geraniums." Only a few of the commonest are here described.]

1. P. peltatum Ait. Ivy Geranium. Stems somewhat prostrate and trailing. Leaves somewhat peltate, smooth or nearly so. Flowers pink or white.

2. P. zonale Willd. Horseshoe Geranium. Stem erect, widely branched, woody below. Leaves alternate, opposite or sometimes in threes, round or kidney-shaped, palmately veined, crenate, downy, usually with a dark zone near the middle. Flowers in a long peduncled umbel, showy, red or white, often double. Numberless varieties in cultivation.

3. P. graveolens Ait. Rose Geranium. Stem erect or ascending, densely downy, 1–3 ft. high. Leaves alternate, palmately lobed or divided, the lobes often finely dissected, rolled under at the edges. Flowers umbeled, small, light purple with darker veins; whole plant very fragrant. Common in cultivation.

4. P. odoratissimum Ait. Nutmeg Geranium. Branches crooked and straggling from a very short, moderately stout main stem. Leaves small, roundish and scalloped, covered with velvety down, very fragrant. Flowers white, inconspicuous, on short pedicels the petals hardly longer than the calyx.

49. OXALIDACEÆ. Wood Sorrel Family

Herbs or woody plants. Leaves compound. Flowers in fives, bisexual, actinomorphic, hypogynous. Stamens 10, somewhat monadelphous at the base. Ovary with several ovules in each cell. Fruit a capsule.

OXALIS L.

Acid herbs. Leaves basal or alternate, with or without stipules, usually of 3 leaflets, which droop at night. Sepals 5. Petals 5. Stamens 10. Ovary 5-lobed, 5-celled; styles 5.

1. O. Acetosella L. Wood Sorrel. Apparently stemless, from a creeping, scaly rootstock. Leaves all basal, long-petioled, of 3 inversely heart-shaped leaflets; scape slender, 2–5 in. high, 1-flowered. Flowers nearly 1 in. in diameter, white, veined with red or purple. Cold woods N.

2. O. violacea L. Violet Wood Sorrel. Perennial from a bulbous root, apparently stemless. Leaves long-petioled; leaflets inversely heart-shaped, sometimes slightly downy, often with a dark zone near the middle. Scapes usually longer than the petioles, umbellately 4–10-flowered; pedicels slender. Flowers violet-purple, nodding. Petals obtuse, 2–3 times as long as the sepals; scapes and petioles 4–5 in. long. Common in rich woods.*

3. O. corniculata L. Common Yellow Wood Sorrel. Probably flowering the first year but perennial, propagated by slender whitish rootstocks. Erect or decumbent, often sparsely hairy, usually 1 ft. or less in height. Stem leafy, the leaves often appearing whorled. Leaflets thin, green or purplish, often ciliate. Peduncles few-flowered, the ascending pedicels, clad with spreading hairs, forming unsymmetrical umbels or cymes at their summits. Flowers yellow, about $\frac{1}{3}$ in. in diameter. Pods hairy, columnar, grooved, often $\frac{1}{2}$ in. or more in length. A common weed in light soil.

50. TROPÆOLACEÆ. Indian Cress Family

Smooth and tender herbaceous plants, with biting juice, often climbing by the petioles of their simple leaves. Leaves alternate, without stipules. Peduncles axillary, 1-flowered. Sepals 3–5, the upper one with a long, distinct spur. Petals 1–5, hypogynous, not always all alike. Stamens 6–10, perigynous,

distinct. Ovary 1, 3-angled, made up of 3–5 1-ovuled carpels; style 1; stigmas 3–5. Fruit not opening.

TROPÆOLUM L.

Characteristics of the genus those of the family above given, together with the following:

Petals usually 5, clawed, the 2 upper inserted at the mouth of the spur and unlike the 3 lower ones. Stamens 8, ripening unequally, the filaments curved. Fruit 3-celled, 3-seeded. Cultivated from S.A. for the very showy flowers and the sharp-flavored fruits, which are often pickled.

1. T. majus L. Common Nasturtium. Climbing by the petioles 6–8 ft. (there is also a low variety which does not climb). Leaves roundish but more or less 6-angled, peltate, with the petiole attached near the middle. Flowers varying from almost white to nearly black, but commonly crimson, scarlet, or flame color.

51. LINACEÆ. Flax Family

Herbs, shrubs, or trees. Leaves usually alternate, simple, entire, sometimes with stipules. Flowers variously clustered. Sepals 5, distinct or united. Petals 5, hypogynous. Stamens 5, monadelphous below. Pod 8–10-seeded, with twice as many cells as there are styles.

LINUM L.

Herbs or small shrubs, with tough, fibrous bark. Leaves sessile. Flowers in corymbs or panicles. Sepals 5, entire. Petals 5, distinct or united below, falling in a few hours after expanding.

1. L. usitatissimum L. Common Flax. Stem erect, with corymbed branches at the top. Leaves narrowly lanceolate. Flowers handsome, large, blue. Cultivated for the fiber. From Europe; introduced here to some extent.

2. L. virginianum L. Wild Flax. Stem rather slender, erect and cylindrical; branches cylindrical. Leaves small, varying from oblong to lanceolate or spatulate, the lower often opposite. Flowers small, yellow. Capsules flattened at right angles to the pedicels. Dry woods and pastures.

52. RUTACEÆ. Rue Family

Shrubs or trees. Leaves alternate, compound, without stipules, marked with translucent dots. Flowers usually actinomorphic. Sepals and petals 3–5 or none; petals hypogynous or perigynous when present. Stamens as many or twice as many as the sepals, inserted on the glandular disk. Pistils 2–5, often partially united. Fruit a capsule, a key fruit, or in the important genus *Citrus* (orange, lemon, lime, etc., not here described) a leathery-skinned berry, the outer part of the skin containing many spherical oil cavities.*

I. XANTHOXYLUM

Trees or shrubs; bark, twigs, and petioles usually prickly; leaves odd-pinnate, marked with translucent dots. Flowers in axillary or terminal cymes or umbels, monœcious or dicœcious. Sepals and petals 3–5 or none. Stamens 3–5, hypogynous. Pistils 2–5, distinct. Carpels 2-valved, 1–2-seeded; seeds smooth and shining.*

1. X. americanum Mill. Northern Prickly Ash, Toothache Tree. A prickly shrub, 8–12 ft. high, with aromatic bark. Leaves pinnately compound; leaflets ovate-oblong. Flowers small and greenish, in axillary umbels, appearing before the leaves. Petals 4–5. Pistils 3–5, the styles slender. Pods rather globose, somewhat more than $\frac{1}{8}$ in. in diameter, roughish, borne on a short stalk above the receptacle, with a strong scent of lemon and tasting at first aromatic, then burning. Rocky woods, ravines, and river banks.

II. PTELEA L.

Shrubs with smooth and bitter bark. Leaves with 3 leaflets. Flowers in terminal cymes, somewhat monœcious. Sepals 3–6, deciduous, much shorter than the petals. Stamens 4–5, longer than the petals and alternate with them. Pistillate flowers producing imperfect stamens. Ovary compressed, 2-celled. Fruit a 2-celled, 2-seeded, broadly winged key.*

1. P. trifoliata L. Hop Tree, Wafer Ash. A shrub 4–8 ft. high. Leaves long-petioled; leaflets oval or ovate, acute, obscurely serrate,

the lateral ones oblique. Cymes compound. Flowers greenish. Stamens mostly 4; filaments bearded; key about 1 in. in diameter; wing notched, strongly netted-veined. Rocky banks; often cultivated.*

53. POLYGALACEÆ. Polygala Family

Herbs or shrubs. Leaves alternate or nearly opposite, without stipules, simple. Flowers not actinomorphic. Sepals unequal, the 2 inner wing-shaped and petal-like. Petals 3–5, hypogynous, the 2 lateral ones often united with the hooded lower one into a tube, split open at the base behind. Stamens 8; filaments united into a split sheath, which is usually joined to the petals; anthers usually opening by pores. Ovary 2-celled, 2-ovuled. [A difficult family for the beginner.]

POLYGALA L.

Herbs or shrubs. Flowers racemed or spiked, some of them often cleistogamous. Petals united below to the stamen sheath. Anthers opening by transverse pores.

1. P. paucifolia Willd. Fringed Polygala, Babies' Toes, May Wings. A low perennial herb, with branches 3–4 in. high, from a slender, creeping rootstock. Lower leaves scattered, small and scale-like, the upper ones with petioles, crowded near the tips of the branches, ovate or nearly so. Flowers of two kinds, the cleistogamous whitish, fertile, borne underground along the rootstock, the terminal flowers large and showy (nearly an inch long), rose-purple, with a beautiful fringed crest. Woods, especially N. and E.

2. P. Senega L. Seneca Snakeroot. A perennial herb, with several erect stems arising from stout, hard, knotty rootstocks. Leaves lanceolate, oblong or lance-ovate, sessile. Flowers all alike, small, white, in solitary close spikes. Rocky woods.

54. EUPHORBIACEÆ. Spurge Family

Herbs, shrubs, or trees, usually with a milky, more or less acrid and sometimes poisonous juice. Flowers mostly apetalous, monœcious or diœcious (Fig. 23). Ovary usually 3-celled, with 1 or 2 ovules in each cell; stigmas as many as the cells

or twice as many. Fruit a 3-lobed capsule. Seeds containing fleshy or oily endosperm. Most of the family are natives of hot regions, many of them of peculiar aspect from their adaptation to life in dry climates. [The family is too difficult for the beginner in botany to determine many of its genera and species with certainty, but a few are described below.]

I. JATROPHA L.

Shrubs or herbs. Leaves alternate. Flowers monœcious, staminate and pistillate intermixed in the cymes, apetalous. Calyx large, white, 5-lobed, corolla-like. Stamens numerous, usually monadelphous. Ovary usually 3-celled, 3-seeded; styles 3, united at the base, several-parted.*

1. J. stimulosa Michx. · Spurge Nettle. Perennial herbs armed with stinging hairs; stems erect, branched, bright green with white lines, 8–15 in. high. Leaves long-petioled, deeply palmately 3–5-lobed, the lobes irregularly cut and toothed, often mottled. Sepals white, spreading. Seeds oblong, smooth, mottled. In dry woods S.*

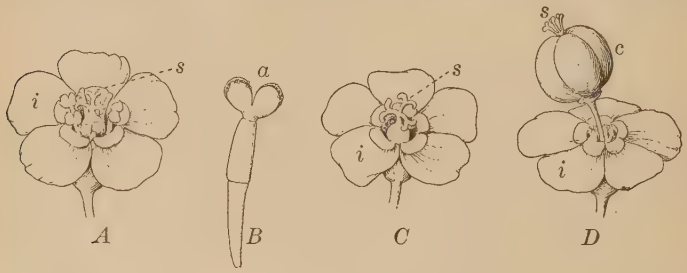


Fig. 23. *Euphorbia corollata*

A, flower cluster with involucre, the whole appearing like a single flower. *B*, a single staminate flower: *a*, anther. *C*, fertile flower, as seen after the removal of the sterile flowers. *D*, partly matured fruit: *i*, involucre; *s*, stigmas; *c*, capsule

II. EUPHORBIA L.

Herbs or shrubs, with milky juice, often poisonous. Flowers monœcious, inclosed in a 4–5-lobed involucre, which is often showy and resembles a calyx or corolla, usually bearing large

glands at its notches. Sterile flowers many, borne inside the involucre at its base (Fig. 23, *A*), each consisting only of a single stamen attached by a joint to a pedicel which looks like a filament. Fertile flower standing alone at the center of the involucre (Fig. 23, *C*) (soon pushed out by the growth of its pedicel), consisting only of a 3-lobed and 3-celled ovary, 3 2-cleft styles, and 6 stigmas. Pod 3-celled and 3-seeded.

A. *Cultivated shrubs.*

1. E. splendens Bojer. Crown of Thorns. An extremely prickly shrub, with many erect, few-leaved branches. Leaves obovate or obovate-spatulate, mucronate, entire, each with two very sharp prickles (longer than the petiole) as stipules. Peduncles long, sticky, each bearing 2–4 objects which appear to be showy scarlet flowers, but which are actually 2-bracted involucres containing the true flowers. Involucral scales somewhat kidney-shaped, mucronate. Flowering all the year round. Cultivated in greenhouses. From Mauritius.

B. *Herbs with rather showy white flower clusters.*

2. E. marginata Pursh. Snow on the Mountain. Annual. Stem stout, 1–3 ft. high. Leaves sessile, ovate, obovate or oblong, acute, ¾–3 in. long, the upper ones whorled and with white petal-like margins. Involucres 5-lobed in an umbel-like inflorescence with three forking rays. In dry soil W. and commonly cultivated.

3. E. corollata L. Flowering Spurge. Perennial. Stem erect, umbellately branched above, smooth or downy, 1–3 ft. high. Leaves of the stem alternate, those of the branches usually opposite or whorled, rather thick, oval to narrowly oblong, pale beneath, usually slightly downy. Flowering branches repeatedly forked; involucres terminal and in the forks of the branches, peduncled; glands 4–5, oblong, green; appendages white and petal-like, showy. Capsule erect, seed smooth or faintly pitted. Common in dry, open woods.

C. *Herbs: No. 4 a native species; No. 5 cultivated from Europe or escaping from gardens. Flower clusters in umbels, not white. Involucre 4- or 5-lobed, each lobe with a gland.*

4. E. dictyosperma Fisch. & Mey. Annual. Stem slender, 8–18 in. high, erect. Stem leaves oblong-spatulate to obovate, serrate; floral ones roundish-ovate, somewhat heart-shaped. Flower cluster a compound umbel, the rays once or twice 3-forked, then 2-forked. Seeds covered with a network. Prairies and roadsides.

5. E. Cyparissias L. Cypress Spurge, Cypress, Graveyard Moss. A perennial, in dense clusters 6–12 in. high, from running rootstocks. Leaves much crowded, all sessile, the stem leaves linear, floral ones broadly heart-shaped. Flower cluster a simple, many-rayed umbel. Glands crescent-shaped. Cemeteries, roadsides, etc., escaped from cultivation; also cultivated in old gardens. From Europe.

55. ANACARDIACEÆ. Sumac Family

Trees or shrubs, with resinous, acrid, or milky sap. Leaves simple, of 3 leaflets or pinnately compound, alternate, without stipules. Flowers bisexual or unisexual, small. Calyx 3–5-parted, persistent. Petals 3–5 or wanting. Stamens as many as the sepals or sometimes twice as many, inserted in the base of the calyx, distinct. Ovary free, 1-celled; styles 1–3. Fruit a 1-seeded drupe.*

RHUS L.

Trees or shrubs. Leaves of 3 leaflets or odd-pinnate. Flowers in spikes or panicles. Calyx mostly 5-parted. Petals and stamens 5. Pistil 1, sessile; styles 3, terminal. Fruit small, smooth or downy.*

1. R. typhina L. Stag-Horn Sumac. A small tree, 20–40 ft. high; branches and petioles closely velvety-hairy. Leaves odd-pinnate, leaflets 17–27, lanceolate-oblong, taper-pointed at the apex, very obtuse at the base, sharply serrate, smooth above, pale and downy beneath. Flowers somewhat monœcious, in dense terminal panicles. Fruit red, with crimson hairs. Dry hillsides N. and E.*

2. R. glabra L. Sumac. A shrub or small tree, sometimes 25–30 ft. high; branches downy. Leaves odd-pinnate, main midrib downy and wing-margined; leaflets 9–21, ovate-lanceolate, acute at the apex, inequilateral, entire or slightly toothed, smooth and green above, pale and downy beneath. Panicle often large and spreading; flowers somewhat monœcious. Fruit red, hairy, acid. Open woods.*

3. R. Vernix L. Poison Sumac, Poison Dogwood. A very smooth shrub with gray bark, 6–18 ft. high. Leaves large and glossy, with 7–13 obovate-oblong, entire leaflets. Flower clusters loosely flowered, axillary panicles. Fruit smooth, greenish-yellow. Swamps and wet openings in woods N. and E. Plant more poisonous than the following species.

nodding on slender peduncles. Corolla not opening widely, orange, striped with reddish-brown veins. Column of stamens projecting beyond the corolla like a tassel. Cultivated in hothouses. From Brazil.

II. MALVASTRUM Gray

Calyx with an involucel of 2 or 3 bractlets or none. Petals notched at the end or entire. Styles 5 or more, with knobbed stigmas. Carpels not splitting open or somewhat 2-valved, falling from the axis when mature, tipped with a point or beak.

1. M. coccineum Gray. Red False Mallow. Perennial, 4–10 in. high, covered with a dense silvery down of star-shaped hairs. Leaves 3–5-parted. Flowers in short spikes or racemes. Petals red, much longer than the calyx. Carpels 10 or more, with a wrinkled network on the sides. Prairies W. and S.W.

III. MALVA L.

Calyx 5-cleft, with a small, 3-leaved involucel. Petals obcordate or truncate. Styles many, slender, with stigmas running down the sides. Carpels many, 1-seeded, arranged in a circle and separating from each other, but not opening when ripe.

1. M. rotundifolia L. Common Mallow, Cheeses (from appearance of the unripe fruit). A common biennial or perennial weed, with nearly prostrate stems. Leaves long-petioled, round-kidney-shaped, with crenate margins. Flowers small, whitish, on long peduncles.

2. M. sylvestris L. High Mallow. Biennial or perennial. Stem erect, 2–3 ft. high. Leaves 5–7-lobed. Flowers purplish, larger than those of the preceding species.

IV. CALLIRHOË Nutt.

Calyx naked, or with a 3-leaved involucel at the base. Petals wedge-shaped, often toothed and fringed. Styles and stigmas as in *Malva*. Carpels 10–20, joined in a circle, 1-seeded, beaked at the tip.

1. C. alcæoides Gray. Light Poppy Mallow. Perennial. Stems rather slender, 8–20 in. high, covered with close-lying stiff hairs. Basal leaves triangular-heart-shaped, palmately lobed or incised;

stem leaves palmately divided. Involucel none. Flowers pink or white, about 1 in. in diameter. Carpels strongly wrinkled. In dry soil W. and S.W.

2. C. digitata Nutt. Fringed Poppy Mallow. Resembling *C. alcæoides*. Flowers $1\frac{1}{2}$–2 in. in diameter. Petals reddish-purple to white, fringed. In dry soil S.W.

3. C. involucrata Gray. Purple Poppy Mallow. Perennial. Stems 1–2 ft. high, procumbent or ascending. Leaves round-heart-shaped, palmately lobed or cut. Involucel 3-leaved. Peduncles long, slender, and 1-flowered. Flowers reddish-purple, 1–$2\frac{1}{2}$ in. in diameter. Carpels with a wrinkled network. In dry soil W. and S.W.

66. HYPERICACEÆ. St. John's-wort Family

Herbs, shrubs, or trees. Leaves opposite, often covered with translucent or dark dots, entire or with glandular teeth, without stipules. Flowers usually in terminal cymes. Sepals 5, rarely 4. Petals as many as the sepals, hypogynous. Stamens usually many, more or less grouped in bundles; anthers versatile. Pod 1-celled, with 2–5 parietal placentæ and the same number of styles, or else 3–7-celled, splitting along the partitions.

HYPERICUM L.

Herbs, shrubs, or small trees. Leaves sessile, often dotted. Flowers yellow, bisexual.

B. Fl. species 2 (*Sarothra*).

1. H. perforatum L. Common St. John's-wort. Perennial. Stem erect, 1–3 ft. high, 2-ridged, much branched. Leaves linear or oblong, obtuse, with translucent veins and dots. Cymes grouped in corymbs, many-flowered. Flowers 1 in. in diameter. Sepals acute. Petals much longer than the sepals, oblique at the tip and irregularly fringed. A common weed in meadows and pastures E. and N. Naturalized from Europe.

2. H. gentianoides BSP. Orange Grass, Pineweed. Low (4–9 in. high), slender annual, with erect, angled or almost winged, wiry stem and branches. Leaves minute awl-shaped scales. Corolla about $\frac{1}{4}$ in. in diameter, usually closing by or before midday. Sandy banks and roadsides.

67. VIOLACEÆ. Violet Family

Herbs, with simple, alternate leaves, with stipules. Calyx of 5 persistent sepals. Corolla of 5 petals, somewhat zygomorphic; one petal with a spur. Stamens 5, short, the filaments often united around the pistil (Fig. 24). Style generally club-shaped, with a one-sided stigma, with an opening leading to its interior. Pod 1-celled, splitting into 3 valves, each bearing a placenta. The seeds are often dispersed by the splitting of the elastic valves (Fig. 24).

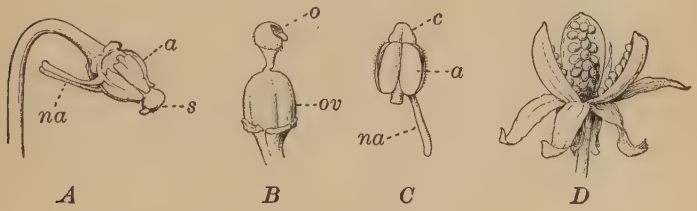


Fig. 24. *Viola tricolor*

A, stamens and pistil; *B*, pistil with stamens removed; *C*, stamen; *D*, pod split open. *a*, anther; *c*, connective; *na*, nectarial appendage of stamen; *o*, orifice in stigma; *ov*, ovary; *s*, stigma. (*A*, *B*, and *C* considerably magnified)

VIOLA L.

Sepals ear-like at the base. Some of the petals often bearded within, thus affording a foothold for bees, the lowest one with a spur at the base. Stamens not very much united, the two lowermost with spurs which reach down into the spur of the lowest petal. Many species bear inconspicuous apetalous flowers later than the showy ordinary ones, and produce most of their seed from these closed, self-fertilized flowers.

§ 1. *Apparently stemless perennials*

1. V. pedata L. Bird-Foot Violet, Horseshoe Violet, Sand Violet. Rootstock stout, upright, not scaly. Leaves roundish, all palmately 5–9-parted into linear or linear-lanceolate divisions. Flowers showy, about 1 in. broad, pale violet to whitish; petals not bearded. Dry fields and hillsides.

2. V. cucullata Ait. Marsh Blue Violet. Leaves acute, except the earliest ones. Petal-bearing flowers violet blue, with a darker center; peduncles usually longer than the leaves, the spur-bearing petal smooth. Sepals narrowly lanceolate, with long ear-like appendages. Cleistogamous flowers borne on erect or ascending peduncles. Capsule not much longer than the sepals. Wet ground, common.

3. V. papilionacea Pursh. Common Blue Violet, Dooryard Violet. Plants usually strong and vigorous from a thick horizontal rootstock, usually smooth. Leaves bright green, cordate at the base, somewhat triangular or rounded and pointed. Scapes at the time of flowering longer than the leaves. Petals dark violet-purple, white or greenish-yellow at the base, the one with a spur often narrow and boat-shaped. Capsules from the cleistogamous flowers borne on horizontal peduncles and often underground, but rising as they mature. Very common about dwellings and gardens.

4. V. palmata L. Early Blue Violet. Usually downy. Petioles much longer than the blades; leaves, except the earliest ones, cordate-ovate, with 5–9 variously toothed or cleft segments; the petioles and the veins of the under surface very hairy. Scapes not usually longer than the leaves. Sepals lanceolate, acute or taper-pointed. Petals violet-purple, occasionally pale. Capsules from the cleistogamous flowers borne on horizontal or deflexed peduncles. In dry, rich woodlands.

5. V. sororia Willd. Woolly Blue Violet. In size and appearance much like No. 3. Leaves ascending, mostly ovate or roundish-ovate, pointed, cordate at the base, crenate, densely soft-hairy when young. Peduncles hairy; petals varying from violet to lavender. Cleistogamous flowers on short prostrate peduncles. Moist meadows and rich woods.

6. V. fimbriatula Sm. Ovate-Leaved Violet. Rootstock usually erect, at length long and stout. Petioles generally shorter than the blades; leaves varying from ovate-lanceolate to oblong, usually slightly crenate, truncate or almost cordate at the base. Petals blue, bearded. Capsules of the cleistogamous flowers borne on erect peduncles. In dry woods.

§ 2. *Leafy-stemmed perennials*

7. V. pubescens Ait. Downy Yellow Violet. Soft-downy, 6–12 in. high. Basal leaves ovate-kidney-shaped, soon withering; stem leaves broadly heart-shaped, toothed, pointed, with large stipules. Flowers yellow, somewhat purple-veined, with a short spur. In dry woods, common.

8. V. scabriuscula Schwein. Smoothish Yellow Violet. Like *V. pubescens*, but smaller, greener, and less downy. Stems decumbent or ascending. Basal leaves broadly ovate, usually persistent through

the flowering period. Flowers pale yellow, purple-veined. In moist woods and thickets.

9. V. canadensis L. CANADA VIOLET. Stems tufted, very leafy, smooth, 1 ft. or more high. Leaves heart-shaped, acute or taper-pointed, serrate; stipules lanceolate, entire. Flowers large and handsome. Petals white or nearly so, inside, the upper ones usually violet-tinged beneath; lateral petals bearded. In rich woods, especially of hilly regions.

10. V. striata Ait. STRIPED VIOLET. Similar to *V. canadensis*, but the stipules dentate, pinnately cut, or fringed. Petals cream-colored, white, or bluish, distinctly veined. Moist woods and thickets.

§ 3. *Leafy-stemmed, from an annual, biennial, or occasionally short-lived perennial root; stipules about as large as the blades of the leaves.*

11. V. tricolor L. PANSY, HEART'S-EASE. Stem branching, angular, hardly erect. Leaves variable, more or less ovate, crenate or crenate-serrate. Flowers large (often more than 1 in. across), flattish, short-spurred, exceedingly variable in color. Cultivated from Europe.

12. V. arvensis Murr. FIELD PANSY. Similar to *V. tricolor*, but the whole plant smaller and more slender. Leaves narrow, often lanceolate, the stipules dissected into narrow divisions. Petals all yellow, equaling or shorter than the slender, pointed sepals. Common in old fields. Naturalized from Europe.

13. V. Rafinesquii Greene. WILD PANSY. Annual, slender, often branching from the base. Leaves small, the earlier ones roundish, on slender petioles; the later ones obovate or narrower, tapering to the base. Flowers small, yellowish-white to bluish-white. Petals much longer than the linear sepals. Woods and fields.

68. PASSIFLORACEÆ. PASSION FLOWER FAMILY

Shrubs or herbs, climbing by axillary tendrils. Leaves alternate, simple, mostly 3-lobed. Flowers axillary, on jointed peduncles, solitary or few together, bisexual, actinomorphic, often showy. Calyx tube 4–5-lobed, persistent. Petals usually 5, inserted on the throat of the calyx tube, which is fringed with a crown of 1–3 rows of long and slender filaments. Stamens 5, their filaments united, and inclosing the stalk of the ovary. Styles 1–5; ovary with 3–5 parietal placentæ. Seeds numerous; fruit fleshy.

PASSIFLORA L.

Characters of the family.

1. P. incarnata L. Passion Flower. Perennial. Stem often 20–30 ft. long, somewhat angled or striate, smooth below, downy above. Leaves broadly heart-shaped, palmately 3–5-lobed; the lobes acute, finely serrate, usually heart-shaped at the base; petiole bearing 2 oval glands near its summit. Flowers 2–3 in. wide, solitary; peduncles 3-bracted, longer than the petioles; calyx lobes with a small horn-like appendage on the back near the apex, white within. Petals and crown purple and white. Fruit yellow, about the size and shape of a hen's egg, edible. Seeds with a pulpy aril. Common along fence rows and embankments S.*

2. P. lutea L. Yellow Passion Flower. Perennial. Stem slender, smooth, 6–10 ft. long. Leaves broadly heart-shaped, 3-lobed at the summit, entire, often mucronate; stipules small; petioles without glands. Peduncles longer than the leaves, usually in pairs. Flowers greenish-yellow, ½–¾ in. wide. Fruit purple, oval, ½ in. long. Woods and thickets S.*

69. BEGONIACEÆ. Begonia Family

Chiefly perennial herbs or low shrubs, with fleshy or very juicy stems. Leaves alternate, generally heart-shaped at the base, often very unsymmetrical; stipules deciduous. Flowers monœcious, in cymes or other clusters, on axillary peduncles. Stamens many (Fig. 25). Pistillate flowers with the floral envelopes borne on the ovary. Ovary 3-angled or 3-winged (Fig. 25), very many-seeded.

BEGONIA L.

Flowers with the calyx and corolla of the same color, staminate and pistillate ones both occurring in the same cluster. Sepals usually 2. Petals 2 or in the fertile flowers 3 or 4, sometimes wanting. Stamens many in a cluster, with short filaments. Styles of the fertile flowers 3, often with long, twisted stigmas (Fig. 25, *C*). The genus contains a great number of species and varieties, cultivated from tropical or subtropical regions, of which only a few of the commonest are here described.

1. B. Rex Putz. Herb, apparently stemless or nearly so, from a fleshy rootstock. Leaves large, taper-pointed, very unequally heart-shaped; the margin sinuous, often bristly-fringed; upper surface wholly silvery, or mottled silvery and dark green; lower surface green or reddish, or of both colors. Flowers few, large ($1\frac{1}{2}$–$1\frac{3}{4}$ in. in diameter), varying from yellow to pinkish. Cultivated from the Himalayas. Many varieties.

2. B. manicata Brongn. Herb, with a short and fleshy stem. Leaves very unevenly heart-shaped, taper-pointed; the margins bristly-fringed and sometimes with very remote teeth; upper surface dark green, lower surface and petioles partly covered with long fringed scales; stipules larger and fringed. Flowers flesh-colored, handsome, in a loose panicle borne on a long peduncle. Cultivated from Mexico.

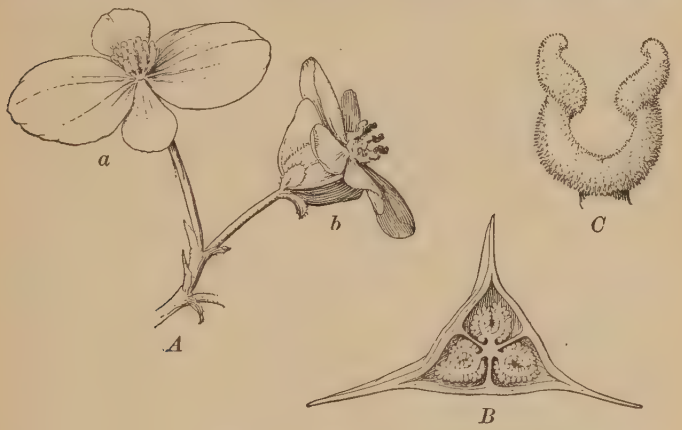


FIG. 25. Begonia flowers

A: *a*, staminate flower; *b*, pistillate flower. *B*, cross section of ovary; *C*, twisted stigmas, enlarged

3. B. coccinea Hook. Tall, 3–10 ft. high, somewhat shrubby, often with many erect, smooth stems from the same root. Leaves broadly and unevenly lanceolate or ovate-lanceolate, half heart-shaped or broadly one-eared at the base, acute, nearly or quite entire, smooth, dull green above, sometimes tinged with red below. Peduncles several–many-flowered, reddish, slender, somewhat nodding. Flowers showy, medium-sized, scarlet. Fruit showy, scarlet, very broadly winged. Cultivated from Peru. [Often called *B. rubra.*]

4. B. incarnata L. & O. Herbaceous or mainly so, rather tall (2–4 ft.), stems clustered, slightly reclining, hairy when young, at length smoother. Leaves broadly and very unequally ovate-lanceolate, tapering toward the tip but at the extremity somewhat blunt, half heart-shaped at the base, somewhat lobed and sinuate-toothed, rough-hairy above and below and on the petioles, dark green above with coppery streaks along the veins. Flowers on short peduncles, few, of medium size; beautiful rose-pink in the bud, becoming almost white; thickly covered outside with soft, moss-like hairs. Cultivated from Mexico. [Often called *B. metallica.*]

5. B. semperflorens L. & O. Stems smooth, herbaceous, rather fleshy, branching near the ground and reclining. Leaves obtuse or nearly so, broadly ovate, somewhat unevenly heart-shaped or tapering at the base, irregularly serrate or scalloped and wavy, smooth, dark green, and very glossy above; stipules rather large, nearly ovate. Flowers in small, axillary clusters near the top of the stem; whitish to crimson, about $1\frac{1}{4}$ in. in diameter. Ovary in fruit very broadly winged. An easily grown but homely species. Cultivated from S. Brazil.

70. CACTACEÆ. Cactus Family

Plants usually with very fleshy and much thickened, often globular or cylindrical, stems. Leaves usually wanting. Flowers sessile, solitary, often very showy. Perianth epigynous, consisting of several rows of sepals and petals. Stamens many, with slender filaments, borne on the inside of the perianth tube. Style 1; stigmas numerous; ovary 1-celled, many-ovuled. Fruit a many-seeded berry.

I. OPUNTIA L.

Stem composed of a series of flattened joints, which are usually leafless when full grown. Leaves very small, awl-shaped, spirally arranged, appearing on the young joints but soon dropping off, with barbed bristles and sometimes spines in their axils. Flowers yellow. Sepals and petals not much united into a tube. Fruit often eatable.

1. O. vulgaris Mill. Common Prickly Pear. Prostrate or nearly so, pale green. Leaves about $\frac{1}{6}$ in. long, rather scale-like; bristles many, with few or no spines. Flowers 2 in. or more in diameter,

with about 8 petals. Fruit about 1 in. long, crimson when ripe, eatable. Dry rocks and sandy ground, from Massachusetts south along the coast.

2. O. **Rafinesquii** Engelm. Prostrate, green. Leaves $\frac{1}{4}$–$\frac{1}{3}$ in. long, awl-shaped, spreading; bristles often intermixed with a few small spines and a larger one $\frac{3}{4}$–1 in. long. Flowers larger than in No. 1 and with 10–12 petals. Fruit about $1\frac{1}{2}$ in. long, much tapered at the base. In poor soil.

3. O. **polyacantha** Haw. Prostrate, light green. Leaves very small, with bristles and 5–10 spines in their axils. Flowers 2–3 in. in diameter. Fruit dry and spiny. Wisconsin, S. and W.

II. PHYLLOCACTUS Link.

Stems cylindrical when old, with long, flattened, fleshy but leaf-like, sinuate or serrate branches. Flowers nearly or quite regular, from the notches in the margins of the joints.

1. P. **Ackermanni** Solm. D. Flowers very showy, bright red. Perianth tube shorter than the petals. Sepals scattered, small and bract-like. Petals many, 2–3 in. long, widely spreading, somewhat channeled, sharp-pointed. Cultivated from Mexico.

III. CEREUS L.

Stem more or less prismatic but strongly ridged, with bundles of spines borne on the ridges; sometimes prostrate or trailing, sometimes erect, columnar, and 50 or 60 ft. high. Flowers usually showy, borne on the sides of the stem, generally with a rather long perianth tube, which is covered outside with scale-like sepals, usually with tufts of wool in their axils. Petals many, mostly long and spreading.

1. C. **speciosus** K. Sch. Stems 2–3 ft. high, with 3–4 broad-winged and sinuate ridges. Flowers open in the daytime and lasting several days, red or crimson, very showy. Petals longer than the tube, stamens white, drooping, very numerous. Commonly cultivated from Mexico.

2. C. **grandiflorus** Mill. Night-Blooming Cereus. Stems long, climbing by aërial roots, nearly cylindrical, but with 5 or more blunt angles. Flowers very showy, opening only for one night, wilting early in the morning, extremely fragrant. Sepals dull yellow. Petals pearly white, spreading, 6–8 in. long. Cultivated from Mexico.

71. ONAGRACEÆ. Evening Primrose Family

Herbs, rarely shrubs or trees. Leaves opposite or alternate, without stipules. Flowers actinomorphic. Limb of the calyx epigynous, 2–4-lobed. Petals 2–4, rarely wanting, quickly falling off. Stamens 1–8. Ovary usually 4-celled; style thread-like; stigma entire or 4-lobed; ovules 1 or more in the inner angle of each cell. Fruit a capsule, berry, or drupe. Seeds 1 or more, smooth or hairy.

I. ŒNOTHERA L.

Herbs, rarely shrubby. Leaves alternate. Flowers large, yellow, red, or purple. Calyx tube 4-angled. Petals 4. Stamens 8. Capsule usually 4-celled, many-seeded.

B. Fl. species 1 (*Onagra*); species 2, 3 (*Kneiffia*); species 4 (*Hartmannia*); species 5 (*Megapterium*).

1. Œ. biennis L. Common Evening Primrose. Annual or biennial. Erect and usually stout, 1–5 ft. high, stem usually simple, more or less downy and hairy. Leaves lanceolate, acute or taper-pointed, sessile or the lower ones petioled. Flowers bright yellow, 1–2 in. in diameter, opening in the evening. Pod oblong, narrowed above, erect, nearly cylindrical. In dry soil.

2. Œ. pumila L. Small Sundrops. Perennial. Stem erect, finely downy, 4–24 in. high. Leaves usually smooth, entire, obtuse or nearly so, the basal ones spatulate, those of the stem varying from oblanceolate to lanceolate. Spikes loose, nodding when young. Flowers $\frac{1}{3}$–1 in. in diameter. Pods slightly glandular-downy, club-shaped, $\frac{1}{4}$–$\frac{1}{2}$ in. long. In dry soil.

3. Œ. fruticosa L. Sundrops. Biennial or perennial. Stem erect, often rather stout, 1–3 ft. high, downy or sometimes smooth. Leaves lance-oblong, or in one variety linear or nearly so, usually minutely toothed. Racemes often corymbed. Flowers open in the daytime, showy, yellow, 1–2 in. in diameter. Pod nearly sessile, ellipsoidal, with prominent ribs and strong wings. Dry soil, common.

4. Œ. speciosa Nutt. Showy Primrose. Perennial. Stem downy, erect or somewhat decumbent, 6 in.–3 ft. high. Leaves broadly lanceolate to linear, sinuate-denticulate or sinuate-pinnatifid, 2–3 in. long. Flowers opening in the daytime, few, 1$\frac{1}{2}$–3$\frac{1}{2}$ in. in diameter, white to pale pink. Pod strongly 8-ribbed. Prairies S.W.

5. Œ. missouriensis Sims. Perennial. Stems low, decumbent, with short, silky down. Leaves thick, from oval to linear, usually lanceolate, narrowed to a slender petiole, 2–6 in. long, entire or remotely toothed. Flowers axillary, yellow, 3–6 in. in diameter. Capsule orbicular, with broad wings. In dry soil S.W.

II. FUCHSIA L.

Herbs, shrubs, or trees. Leaves opposite or 3 in a whorl. Flowers showy. Calyx colored, tubular-funnel-shaped, the tube extending much beyond the ovary, the margin 4-lobed. Petals 4, borne in the throat of the calyx. Stamens 8, projecting outside the corolla. Capsule berry-like, ellipsoidal, 4-angled.

1. F. macrostemma R. & P. Common Fuchsia, Ladies' Eardrops. Smooth. Leaves slender-petioled, toothed. Flowers on long, drooping peduncles from the axils of the leaves. Calyx tube oblong or a short cylinder, not as long as its spreading lobes. Petals obovate and notched, wrapped spirally around the projecting filaments and style. Found in many varieties, sometimes the calyx white or nearly so and the petals dark or with dark calyx and light petals. Cultivated from Chile.

III. CIRCÆA L.

Slender, erect herbs, with creeping rootstocks. Stem simple. Leaves opposite, petioled. Flowers small, in terminal and lateral racemes. Calyx tube ovoid, the limb 2-parted, reflexed, deciduous. Petals 2, inversely heart-shaped, inserted with the 2 stamens under the margin of a disk which is borne on the pistil. Ovary 1–2-celled; style thread-like; stigma knobbed, 2-lobed; ovules, 1 in each cell. Fruit ovoid, not splitting open, covered with hooked bristles.

1. C. lutetiana L. Enchanter's Nightshade. Stem 1–2 ft. high, glandular-downy. Leaves ovate, faintly toothed, long-petioled. Flowers $\frac{1}{8}$ in. in diameter, white or pink, on slender pedicels, jointed at the base. Damp, shaded places; very common.

72. ARALIACEÆ. Ginseng Family

Herbs, shrubs, or trees. Leaves alternate, simple or compound; stipules united to the petiole or wanting. Flowers regular, in umbels or heads. Limb of the calyx epigynous,

very short. Petals 5, very deciduous. Stamens 5, filaments bent inward, anthers versatile. Ovary 2-celled or several-celled; styles or stigmas as many as the cells; ovules 1 in each cell. Fruit a drupe or berry. [The English ivy, an important member of the family, flowers too late for school study.]

ARALIA L.

Perennial plants, with pungent or spicy roots, bark, and fruit. Leaves once or more compound. Flowers more or less monœcious, white or greenish, in umbels. Drupe, berry-like.

1. A. hispida Vent. Bristly Sarsaparilla, Wild Elder. Stem 1–2 ft. high, rather shrubby below, with prickly bristles. Leaves once or twice pinnate; leaflets ovate, acute, cut-serrate, and often lobed. Peduncle bearing several umbels of cream-colored flowers, in a terminal corymb. Fruit blue-black. Dry fields and pastures E.

2. A. nudicaulis L. Wild Sarsaparilla. Perennial herb. Roots very long, somewhat fleshy, aromatic; stem very short or none. Leaf solitary, from a sheathing base, petioled, 6–12 in. long; compound in threes, each division 3–5-pinnate; leaflets oval or ovate, taper-pointed, finely and sharply serrate, smooth above, often downy below. Scape nearly as long as the petiole, usually bearing 3 short, peduncled umbels. Flowers greenish. Styles distinct. Fruit globose, black. In rich woods.

73. UMBELLIFERÆ. Parsley Family

Herbs, usually with hollow, grooved stems. Flowers small, generally in umbels. Limb of the calyx either wanting or present only as a 5-toothed rim or margin around the top of the ovary. Petals 5. Stamens 5, inserted on the disk, which is borne by the ovary (Fig. 26). Ovary 2-celled and 2-ovuled (Fig. 26), ripening into 2 akene-like carpels, which separate from each other. Each carpel bears 5 longitudinal ribs, in the furrows between which secondary ribs frequently occur. On a cross section of the fruit oil tubes are seen, traversing the interspaces between the ribs, and near the surface of the fruit (Fig. 26, *D*). The seeds contain a small embryo, inclosed in considerable endosperm. [The family is a difficult one,

since the flowers are so much alike that the species are distinguished from each other mainly by minute characteristics of the fruit.]

I. ERYNGIUM L.

Annual, biennial, or perennial herbs. Stems erect or creeping. Leaves simple, mostly linear and spiny-toothed. Flowers white or blue, in dense, bracted heads or spikes, flowers bracteolate. Calyx teeth rigid, persistent. Petals erect, pointed. Styles slender. Fruit top-shaped, scaly or granular; ribs wanting; oil tubes usually 5, minute.*

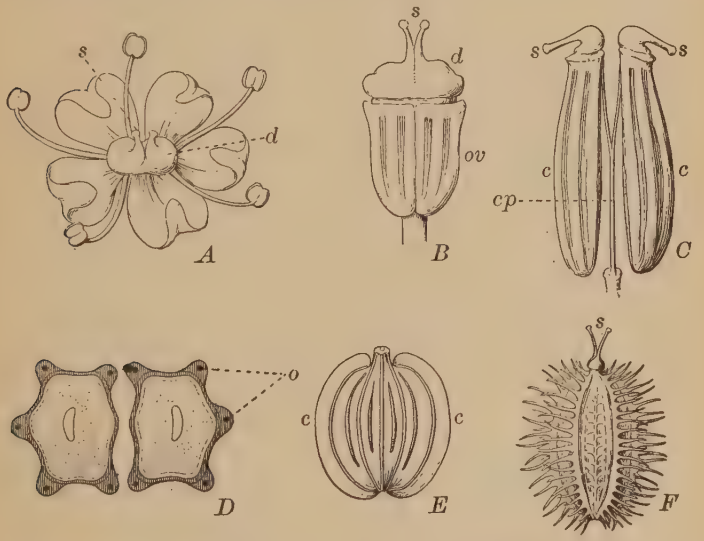


FIG. 26. Flower and fruit of *Umbelliferæ*

A–D, Carum Carvi: A, flower; *B*, partly matured pistil; *C*, mature fruit; *D*, cross section of fruit. *E*, fruit of parsnip; *F*, fruit of carrot. *c*, carpels; *cp*, carpophore, or stalk to which ripe carpels are attached; *d*, disk; *o*, oil tubes; *ov*, ovary; *s*, stigmas. (*A–D*, after Schnizlein; *E*, after Bischoff)

1. E. yuccifolium Michx. BUTTON SNAKEROOT, RATTLESNAKE MASTER. Perennial. Stem erect, branched above, striate, covered with a bloom, 2–3 ft. high. Leaves linear, often 2 ft. or more in

length, rigid, covered with a bloom, parallel-veined, fringed with white bristles. Bracts shorter than the heads, entire; bractlets similar but smaller. Flowers white. Fruit scaly. In damp soil.*

II. SANICULA L.

Slender, erect, perennial herbs. Rootstock short, stout, creeping. Leaves palmately cut. Umbels small, somewhat globular, irregularly compound; bracts leafy; bractlets few; flowers bisexual or staminate, greenish or yellowish. Calyx teeth as long as the small petals, sharp-pointed. Fruit ovoid, covered with hooked prickles, ribless, each carpel with 5 oil tubes.

1. S. marilandica L. Sanicle, Black Snakeroot. Perennial. Stem rather stout, 1–4 ft. high. Leaves 3–7-parted, the divisions irregularly serrate or dentate and often cut. Flowers bisexual and staminate, the latter in separate heads. Petals greenish-white, very small. Styles slender, recurved, and longer than the prickles of the fruit. Rich woods.

2. S. gregaria Bicknell. Clustered Snakeroot. Stems generally clustered, 1–3 ft. high. Leaves 5-divided, obovate-wedge-shaped to lanceolate. Some of the staminate flowers in separate heads. Petals yellow, much longer than the calyx. Styles longer than the prickles of the fruit. Woods and thickets.

3. S. canadensis L. Short-Styled Snakeroot. Leaves petioled, 3–5-divided. Staminate flowers never in separate heads. Styles shorter than the prickles of the fruit. In woodlands.

III. ERIGENIA Nutt.

A little smooth plant, with a slender, unbranched stem, from a deep, nearly globular tuber. Leaves 1 or 2, twice or thrice compound in threes. Flowers few, small, in an imperfect leafy-bracted umbel. Calyx teeth wanting. Petals obovate or spatulate. Fruit smooth, roundish, notched at both ends, the two carpels touching only at top and bottom, each with 5 slender ribs.

1. E. bulbosa Nutt. Harbinger of Spring, Turkey Pea, Pepper-and-Salt. Stem scape-like, with a leaf which forms an involucre to the flower cluster. Petals white, anthers brown-purple. A pretty, though inconspicuous plant; welcomed as one of the earliest spring flowers S.

IV. OSMORHIZA Raf. (WASHINGTONIA)

Perennials, springing from stout, aromatic roots. Leaves compound in threes. Flowers white, in compound umbels. Calyx teeth wanting. Fruit linear or nearly so, tapering at the base, with 5 equal bristly ribs, without oil tubes.

1. **O. Claytoni** Clarke. HAIRY SWEET CICELY. Rather stout and hairy, especially when young, 1½–3 ft. high. Lower leaves on long petioles, large, twice compound in threes, the divisions ovate or oval, cut-toothed; upper leaves nearly sessile, less compound. Umbels with long peduncles and spreading rays. Style and its enlarged base somewhat conical. Root nauseous. Rich woods.

2. **O. longistylis** DC. SMOOTH-LEAVED SWEET CICELY. Much like No. 1 in general appearance. Smooth or nearly so. Style rather thread-like. Root of a pleasant aromatic flavor (as is also the fruit). Woods.

Caution. So many plants of this family have actively poisonous roots and foliage that it is unsafe for any one but a botanist, who can distinguish the poisonous species from the harmless ones, to taste them.

V. CARUM L.

Herbs, with slender, smooth stems. Leaves pinnately compound, smooth. Umbels compound. Flowers white or yellowish. Calyx teeth minute. Fruit smooth, oblong or ovate, with thread-like ribs; oil tube single in the intervals between the ribs; base of the styles thickened into a conical mass.

1. **C. Carvi** L. CARAWAY. Perennial. Leaves large, with the leaflets cut into numerous thread-like divisions. Flowers white. Fruit aromatic, used somewhat in this country and more in N. Europe for flavoring cookies, bread, etc. Introduced from Europe.

VI. ZIZIA Koch.

Smooth perennials. Leaves generally as in *Thaspium*. Involucre wanting; involucels of small bractlets. Umbels compound. Flowers yellow. Calyx teeth prominent. Fruit more or less ovoid, smooth, with thread-like ribs; oil tubes large and solitary between the ribs, and a little one in each rib; the central fruit of each umbellet sessile.

I. CORNUS L.

Trees, shrubs, or herbs. Leaves usually opposite. Flowers in forking cymes, or in umbels or heads, each with an involucre, white or yellow. Calyx teeth 4. Petals 4. Stamens 4. Ovary 2-celled. Drupe ovoidal or ellipsoidal, the stone 2-celled.

1. C. canadensis L. Dwarf Cornel, Bunchberry, Pudding Berry. Stem herbaceous, excepting at the base, low (3–9 in.), and unbranched. Rootstock rather woody, slender, and creeping. Leaves in what appears to be a whorl of 4 or 6 at the summit of the stem, sessile, ovate, oval or nearly so, acute at each end, entire, smooth or very slightly downy. Flower stalk slender, $\frac{1}{2}$–$1\frac{1}{2}$ in. long, with a whorl of 4–6 large, white, petal-like bracts, forming an involucre round the small head of greenish flowers; the head with its involucre appearing to others than botanists like a single flower. Fruit nearly spherical, scarlet, about $\frac{1}{4}$ in. in diameter, in a close cluster, sweet and eatable, though rather insipid. Damp woods, especially N.

2. C. florida L. Flowering Dogwood. Small trees; bark rough, black. Leaves opposite, petioled, ovate to ovate-lanceolate, entire, green and shining above, paler and often downy beneath. Flowers small, greenish, in heads which are subtended by 4 large, white or pink, inversely heart-shaped bracts, thickened and greenish at the notch. Fruit ovoid, bright red. In rich woods S. and E.*

3. C. circinata L'Her. Round-Leaved Dogwood. A shrub 3–10 ft. high, with green, warty twigs. Leaves petioled, roundish-oval, contracted to an abrupt point, entire, usually rounded or truncate at the base, pale and soft-downy beneath. Flowers in flat cymes, $1\frac{1}{2}$–$2\frac{1}{2}$ in. in diameter. Fruit globose, light blue, $\frac{1}{4}$ in. or less in diameter. Thickets often in rocky soil N. and along Allegheny Mountains.

4. C. Amomum Mill. Kinnikinnik. A shrub 6–10 ft. high; twigs purple, downy when young. Leaves opposite, petioled, ovate or oblong, taper-pointed, smooth above, silky-downy below. Flowers white, in rather close cymes. Fruit blue, stone somewhat oblique. In low woods.*

5. C. asperifolia Michx. Rough-Leaved Dogwood. A shrub 8–12 ft. high; twigs slender, reddish-brown, often warty, densely downy when young. Leaves opposite, short-petioled, lance-ovate or oblong, acute or taper-pointed, with rough down above, downy-woolly below. Cymes flat, spreading, the peduncle and branches covered with rough down. Flowers white. Fruit white or pale blue, stone depressed-globose. In dry woods.*

6. C. stolonifera Michx. Red Osier Dogwood. A shrub 3–15 ft. high, with smooth, reddish-purple bark on all the younger twigs; spreading by suckers from the base and therefore the stems usually clustered. Leaves on rather slender petioles, acute or taper-pointed, rounded or tapered at the base; covered, at least beneath, by very fine, closely appressed hairs. Fruit white or nearly so, globose, $\frac{1}{4}$ in. or more in diameter. Common in wet ground, especially N.

7. C. alternifolia L. f. Alternate-Leaved Dogwood. A shrub or small tree; twigs greenish, striped. Leaves alternate, often clustered at the ends of the twigs, long-petioled, oval, acute at the apex and often at the base, minutely toothed, pale and covered with fine, appressed hairs beneath. Cymes loose and open; flowers white. Fruit deep blue. Banks of streams.*

II. NYSSA L.

Trees or shrubs. Leaves alternate, petioled, entire or few-toothed. Flowers somewhat monœcious or dioecious, the staminate in many-flowered heads or cymes, the pistillate in small clusters or solitary. Calyx tube 5-toothed or truncate. Petals minute or wanting. Stamens 5–10. Ovary 1-celled, 1-ovuled; style long and recurved. Fruit a 1-seeded drupe.

1. N. sylvatica Marsh. Black Gum. A tree with widely spreading branches and dark, rough bark; wood light-colored, very tough; base of trunk often enlarged. Leaves often clustered at the ends of the twigs, oval or obovate, taper-pointed or obtuse at the apex, entire, smooth and shining above, downy beneath, becoming bright red in autumn. Staminate flowers in heads; pistillate flowers 3–10, in a long-peduncled cluster. Fruit ovoid, dark blue or nearly black, $\frac{1}{2}$ in. long; stone slightly ridged. In rich, wet soil S. and E.*

2. N. aquatica L. Tupelo. A large tree, similar to the preceding. Leaves long-petioled, oval or ovate, acute at each end, entire or coarsely toothed, the lower sometimes heart-shaped, smooth above, downy beneath, 4–8 in. long. Staminate flowers in heads; pistillate flowers on long peduncles, solitary. Fruit ovoid, dark blue; stone sharply ridged. In swamps S. and E.*

75. PYROLACEÆ. Pyrola Family

Perennial herbs, evergreen or else pale and without chlorophyll. Petals usually free from each other and falling off separately after flowering. Stamens hypogynous, the anthers

Shrubs with showy flowers. Anthers at first held in pocket-like depressions in the corolla. Kalmia, II

Shrubs with small, mostly white, urn-shaped flowers. Lyonia, III

A prostrate plant, hardly at all shrubby. Leaves rather large, often 1½ in. wide, and veiny. Epigæa, IV

A trailing plant with small (about ¼ in. wide), thick, evergreen leaves. Arctostaphylos, V

B

Shrubs. Flowers epigynous; corolla sympetalous. Fruit a true berry or resembling one.

Fruit a berry-like drupe, with 10 nutlets which resemble seeds. Gaylussacia, VI

Fruit a berry with many small seeds. Vaccinium, VII

I. RHODODENDRON L.

Shrubs, often much branched. Leaves alternate, thin, deciduous. Flowers very showy, in terminal umbels, from scaly buds which became well developed the previous season. Calyx very small, 5-parted. Corolla bell-shaped, the tube long and slender, the limb spreading and somewhat one-sided. Stamens 5 or 10, declined; anthers awnless. Style long and slender, declined; stigma knobbed. Capsule oblong or linear, 5-celled, many-seeded; seeds very small, scale-like.

1. R. viscosum Torr. Swamp Honeysuckle, Swamp Pink. A shrub, 4–6 ft. high; branches hairy. Leaves obovate, leathery, mucronate at the apex, mostly smooth above, downy on the veins beneath; petioles very short. Flowers appearing later than the leaves, white, fragrant, 1½–2 in. long; tube long, glandular-viscid. Capsule erect, ½–⅔ in. long, bristly. In swamps.*

2. R. nudiflorum Torr. Wild Honeysuckle, Election Pink. A branching shrub, 4–6 ft. high; twigs smooth or with a few coarse hairs. Leaves obovate or oblong, ciliate-serrate, downy, becoming smooth above; petioles short. Flowers appearing with or before the leaves, pink or white, sometimes yellowish, fragrant, 1–2 in. wide, tube downy but not glandular. Capsule erect, linear-oblong, ⅔–¾ in. long. Swamps and banks of streams; flowers extremely variable in size and color.*

II. KALMIA L.

Erect and branching shrubs. Leaves alternate, opposite or in threes, entire, leathery, evergreen. Flowers showy, in corymbs, or 1–3 in the axils. Calyx 5-parted. Corolla flat-bell-shaped or wheel-shaped, 5-lobed. Stamens 10, the anthers placed in pouches in the corolla, filaments straightening elastically at maturity and so bringing the anthers in contact with any large insect-visitor. Style long and slender. Capsule globose, 5-celled, many-seeded.

1. K. latifolia L. Calico Bush, Mountain Laurel. A shrub, 4–10 ft. high. Branches stout, smooth. Leaves mostly alternate, petioled, elliptical or oval, acute at each end, smooth and green on both sides. Corymbs terminal, compound. Flowers white to rose color, showy, 1 in. broad. Calyx and corolla glandular; pedicels long, slender, sticky-glandular, erect in fruit; calyx and style persistent. Shady banks on rocky or sandy soil.*

2. K. angustifolia L. Sheep Laurel, Lambkill. A shrub, 1–3 ft. high, with smooth, nearly erect branches. Leaves petioled, opposite or in threes, oblong, obtuse at both ends, dark green above, paler beneath. Corymbs lateral, glandular. Flowers purple or crimson, $\frac{1}{2}$–$\frac{1}{3}$ in. broad. Pedicels slender, recurved in fruit. Calyx downy, persistent. Style persistent; capsule depressed-globose. On hillsides; abundant northward.*

III. LYONIA Nutt.

Shrubs or small trees. Leaves alternate, persistent or falling late. Flowers mostly white, in panicles, racemes, or umbels. Calyx 5-parted; corolla urn-shaped. Stamens 10; filaments hairy, often with teeth or appendages; anthers oblong or ovoid. Capsule globose or nearly so, 5-angled. Seeds sawdust-like, with a loose outer coat.

B. Fl. species 1 (*Pieris*); species 2 (*Xolisma*).

1. L. mariana D. Don. Staggerbush. A smooth shrub, 20–40 in. high. Leaves oval or oblong, smooth above, slightly downy on the veins beneath. Flowers nodding, on leafless shoots. Filaments with 2 teeth near the apex. Capsule ovoid-pyramidal, truncate at its apex. Low, sandy soil. Foliage said to be poisonous.

2. L. ligustrina DC. Male Berry. A minutely downy shrub, 1$\frac{1}{2}$–10 ft. high. Leaves varying from obovate to ovate, finely serrate or entire. Racemes usually leafless, crowded in terminal panicles. Filaments flat, without appendages. Capsule globose. Moist thickets and swamps.

warty green branches. Leaves oblong or oblong-lanceolate, sharply serrate, with little bristle-pointed teeth, both sides smooth and shining except for down occasionally on the midrib and veins below, pointed at both ends. Flowers few in a cluster, longer than their minute pedicels. Corolla oblong, bell-shaped, a little narrowed at the throat, white or pinkish. Berry blue, with much bloom, ripening earlier than the other eatable species, sweeter than No. 5 but not so high-flavored. In dry or sandy soil, especially N.

4. V. vacillans Kalm. LATE LOW BLUEBERRY. A low, stiff, smooth shrub, 1–3 ft. high; branches yellowish-green. Leaves obovate or oval, pale or dull green, smooth beneath, entire or nearly so. Flowers greenish-yellow or somewhat pink. Berries late-ripening, blue, with some bloom, sweet. Dry, especially sandy, soil.

5. V. corymbosum L. HIGH-BUSH BLUEBERRY. An erect shrub, 6–12 ft. high; branches stiff, young twigs minutely warty. Leaves deciduous, oval to ovate-lanceolate, acute, margins bristly, serrulate, smooth or downy, short-petioled. Racemes numerous, appearing with or before the leaves. Bracts oval or oblong, deciduous. Flowers white or pink. Corolla almost as long as the pedicel, cylindrical. Berry globose, blue or black, flavor slightly acid, pleasant. Common in woods and thickets. Whole plant extremely variable.*

6. V. macrocarpon Ait. CRANBERRY. Stems creeping, thread-like, 1–3 ft. or more in length, the branches not quite erect, sometimes 8 in. high. Leaves usually oval or oblong, obtuse, thickish, evergreen, the younger ones with the margins somewhat rolled under. Flowers nodding. Petals strongly reflexed, deep rose-red inside at the base, pale pinkish or almost white at the tips. Stamens with the filaments hardly $\frac{1}{3}$ as long as the anthers. Fruit red or reddish-purple, ellipsoidal or nearly globose, very acid, much valued for sauce, pies, and jellies. Common in peat bogs and wet meadows N.

77. PRIMULACEÆ. PRIMROSE FAMILY

Herbs, with simple leaves, often most or all of them basal. Flowers bisexual and actinomorphic, generally sympetalous. Stamens commonly 5, inserted on the corolla, opposite its lobes. Pistil consisting of a single stigma and style and a (generally free) 1-celled ovary, with a free central placenta.

A

Leaves all basal.

(*a*) Segments of corolla not reflexed, throat open. Stamens included. Primula, I

(*b*) As in (*a*), but throat of corolla narrowed. Androsace, II

(*c*) Segments of corolla much reflexed. Stamens protruding. Dodecatheon, VIII

B

Stems leafy, at least near the summit.

(*a*) Corolla yellow. No sterile appendages alternating with the stamens. Lysimachia, III

(*b*) Corolla yellow. Sterile appendages alternating with the stamens. Steironema, IV

(*c*) Corolla white. Stems with leaves mostly whorled near the summit. Trientalis, V

(*d*) Corolla scarlet (sometimes white or blue). Stems low, leafy throughout. Anagallis, VI

(*e*) Corolla inconspicuous, pink. Stems leafy, very short. Centunculus, VII

I. PRIMULA L.

Low, perennial herbs, with much-veined basal leaves ; scapes each bearing an umbel of flowers, which are often showy. Calyx tubular, decidedly angled, 5-cleft. Corolla more or less salver-shaped, with the tube widened above the insertion of the stamens ; the 5 lobes of the limb often notched or cleft. Stamens 5, not protruding outside the corolla tube. Capsule egg-shaped, splitting at the top into 5 valves, each of which may divide in halves.

1. P. grandiflora Lam. True Primrose. Leaves spatulate or obovate-oblong. Flowers rising on separate slender pedicels from the leaf axils. Corolla originally pale yellow, but varying to white, red, and many intermediate shades, with a broad, flat limb. Cultivated from Europe.

2. P. sinensis Sabine. Chinese Primrose. A rather coarse, downy plant. Leaves round-heart-shaped, more or less lobed and cut, long-petioled. Flowers large, in umbels, usually rose color or white. Calyx large, inflated and conical. Cultivated as a house plant from China.

II. ANDROSACE L.

Small herbs, with clustered basal leaves. Flowers very small, solitary or umbeled. Calyx 5-cleft, with a short tube. Corolla salver- or funnel-shaped, contracted at the throat, its tube

1. A. arvensis L. Poor Man's Weatherglass, Pimpernel. Annual; stem spreading, widely branched, 4-angled, smooth, 4–12 in. long. Leaves opposite, sessile, ovate, black-dotted beneath. Flowers on peduncles longer than the leaves, nodding in fruit. Corolla fringed with glandular hairs, longer than the acute calyx lobes, bright red (sometimes white or blue), opening in sunshine. Capsule globose, tipped by the persistent style. Introduced, and common in fields and gardens.*

VII. CENTUNCULUS L.

Small annuals, with alternate entire leaves. Flowers axillary and solitary, inconspicuous. Calyx 4–5-parted. Corolla 4–5-cleft, shorter than the calyx, the tube urn-shaped. Stamens 4–5, perigynous, with short filaments. Capsule globose, many-seeded, the top falling off as a lid.

1. C. minimus L. Chaffweed, False Pimpernel. Stems 1–6 in. high. Leaves spatulate or obovate, with short petioles. Flowers small, pink, nearly sessile, parts of the perianth usually in fours. Moist soil W.

VIII. DODECATHEON L.

A smooth, perennial herb, with a cluster of oblong or spatulate basal leaves, fibrous roots, and an unbranched scape, leafless except for an involucre of small bracts at the summit, with a large umbel of showy, nodding flowers. Calyx deeply 5-cleft, with reflexed, lanceolate divisions. Tube of the corolla very short, the divisions of the 5-parted limb strongly reflexed. Filaments short, somewhat united at the base; anthers long, acute, and combining to form a conspicuous cone.

1. D. Meadia L. Shooting Star, Indian Chief. Corolla varying from rose color to white. In rich woods in most of the Middle and Southern states. Often cultivated.

78. EBENACEÆ. Ebony Family

Trees or shrubs. Leaves alternate, entire, pinnately veined, without stipules. Flowers often dicœcious. Calyx free from the ovary, persistent. Stamens 2–4 times as many as the divisions of the corolla. Ovary 3–12-celled; ovules 1 or 2 in each cell. Fruit a berry. Mostly tropical plants.

DIOSPYROS L.

Flowers dicœcious or somewhat monœcious, the staminate ones in cymes, the pistillate ones axillary and solitary. Calyx 4–6-lobed. Corolla 4–6-lobed. Stamens in the staminate flowers usually 16, in the pistillate ones 8, imperfect. Fruit large, with the persistent calyx attached to its base, 4–8-seeded.

1. D. virginiana L. PERSIMMON. Trees, with rough, black bark, and very hard wood. Leaves oval or ovate-oblong, acute or acuminate at the apex, rounded or slightly cordate at the base, entire and dark green, smooth above, pale and often downy beneath, short-petioled, deciduous. Flowers yellowish-white, the parts mostly in fours. Fruit globose, edible when ripe, very astringent when green; seeds large, compressed, often wanting. Fruit ripening late in the fall. Common in old fields and along roadsides S. and S.W.*

79. OLEACEÆ. OLIVE FAMILY

Shrubs or trees. Leaves opposite, simple or odd-pinnate, without stipules. Flowers usually in forking cymes, small, white, greenish or yellow, bisexual or unisexual. Calyx free from the ovary, 4-lobed or wanting. Corolla hypogynous, regular, 4-parted or of 4 separate petals, sometimes wanting. Stamens 2, borne on the petals or hypogynous. Ovary 2-celled. Fruit 1–2-celled, each cell 1-seeded, rarely 2-seeded (in *Forsythia* many-seeded).

I. FRAXINUS Tourn.

Deciduous trees. Flowers dicœcious. Petals wanting (in our species). Stamens 2, hypogynous. Fruit a 1–2-celled key, each cell 1-seeded.

1. F. americana L. WHITE ASH. A large tree; bark rough, gray; wood hard, strong, elastic; twigs and petioles smooth. Leaflets usually 7, ovate to ovate-lanceolate, taper-pointed at the apex, rounded or obtuse at the base, entire or slightly serrate, smooth above, often downy beneath, short-stalked. Flowers mostly dicœcious. Calyx of the pistillate flowers persistent. Key $1\frac{1}{2}$–2 in. long, winged only at the apex; wing spatulate or oblanceolate. In rich woods and swamps.*

2. F. pennsylvanica Marsh. RED ASH. A small tree; bark rough, dark gray; twigs and petioles densely velvety-downy. Leaflets 5–9, oblong-ovate to ovate-lanceolate, taper-pointed at the apex, narrowed

into a short stalk at the base, finely serrate, smooth above, velvety-downy beneath. Calyx of the pistillate flowers persistent. Key 1½–2 in. long, the wing somewhat extended along the sides, oblanceolate or spatulate, often notched. Swamps and moist soil.*

3. F. caroliniana Mill. WATER ASH. A small tree; wood soft, light, and weak; twigs smooth or downy. Leaflets 5–7, ovate or elliptical, acute at the apex, acute or obtuse at the base, entire or slightly serrate, smooth or slightly downy, stalked. Flowers dioecious. Calyx persistent. Key often 3-angled or 3-winged, wings running nearly to the base, oblong or oval, pinnately veined. In swamps and wet soil.*

4. F. quadrangulata Michx. BLUE ASH. A large tree, with wood heavy, but not as tough as No. 1; the most vigorous twigs usually square. Leaflets 7–9, with short stalks, somewhat ovate or lanceolate, acute, sharply serrate. Fruit winged to the base, of nearly the same width throughout, narrowly oblong. Rich woods, especially W.

II. FORSYTHIA Vahl.

Shrubs. Leaves opposite or in threes, appearing later than the flowers, serrate. Calyx very short, deciduous. Corolla yellow, bell-shaped, its lobes long and slender. Stamens inserted on the base of the corolla tube. Pod 2-celled, many-seeded.

1. F. viridissima Lindl. A hardy shrub, with branches erect or nearly so. Leaves all simple, lance-oblong. Calyx lobes half as long as the tube of the corolla. Lobes of the corolla spreading, narrow-oblong. Style equal in length to the tube of the corolla. Cultivated from Asia.

2. F. suspensa Vahl. A hardy shrub, with drooping branches. Leaves broadly ovate, often some of them with 3 leaflets, the lateral leaflets small. Lobes of the corolla longer, broader, and more spreading than in No. 1. Style shorter than the tube of the corolla. Cultivated from Asia. Less common than No. 1; often trained over porches and arbors.

III. SYRINGA L.

Tall shrubs, forking frequently, from the failure of the terminal buds on most branches. Leaves simple, entire. Flowers in close, compound panicles. Calyx 4-toothed. Corolla salver-shaped, the tube long, the limb 4-lobed. Pod dry, flattened at right angles to the partition, 4-seeded.

1. S. vulgaris L. COMMON LILAC. A strong-growing, hardy bush. Leaves ovate, somewhat heart-shaped. Flowers sweet-scented, in very close, large clusters, lilac or white. Corolla lobes concave. Very commonly cultivated from eastern Europe.

2. S. persica L. Persian Lilac. A more slender and less branched shrub than No. 1. Leaves lance-ovate, somewhat narrowed or tapering at the base. Flowers in rather loose clusters, not very sweet-scented, pale lilac or white. Corolla lobes ovate, somewhat bent inward. Pods linear. Cultivated from western Asia, less common than No. 1.

IV. CHIONANTHUS L.

Shrubs or small trees. Leaves simple, opposite, entire, petioled, deciduous. Flowers in panicles borne on wood of the previous season. Calyx small, 4-cleft, persistent. Corolla wheel-shaped, 4-parted, the lobes long and linear. Stamens 2–4, included, inserted on the base of the corolla. Style short; stigma 2-lobed. Fruit a 1-seeded drupe.*

1. C. virginica L. Fringe Tree, Old Man's Beard. A small tree, with smooth, light gray bark and spreading branches. Leaves oval to oblong, acute or obtuse at each end, smooth or slightly downy. Panicles large and loose, leafy-bracted, appearing with the leaves. Flowers on slender, drooping pedicels. Petals 1 in. or more in length. Fruit ovoid, purple, $\frac{1}{2}$–$\frac{2}{3}$ in. long. Along streams, usually on light soil.*

V. LIGUSTRUM L.

Shrubs. Leaves simple, opposite, entire, deciduous or sometimes persistent. Flowers in terminal panicles or similar clusters, white, small. Calyx minutely 4-toothed or truncate. Corolla funnel form, 4-lobed. Stamens 2, short, inserted in the tube of the corolla. Ovary free, 2-celled, 2 ovules in each cell; style short. Fruit a 1–4-seeded, globose berry.*

1. L. vulgare L. Privet. A branching shrub, 4–10 ft. high; branches long and slender. Leaves somewhat leathery, lanceolate to obovate, short-petioled, tardily deciduous. Panicles dense, minutely downy. Flowers $\frac{1}{4}$ in. wide, fragrant. Stamens included. Berries black. Introduced from Europe and used largely for hedges.*

80. GENTIANACEÆ. Gentian Family

Annual or perennial herbs. Leaves entire, usually opposite, sometimes alternate, without stipules. Flowers actinomorphic, solitary or in cymes. Calyx hypogynous, 4–8-toothed or lobed. Corolla hypogynous, wheel-, bell-, or funnel-shaped,

4–8-lobed. Stamens 4–8, inserted on the corolla tube; filaments thread-shaped; anthers facing inwards. Ovary 1–2-celled; ovules many, on 2 opposite placentas. Capsule 1-celled or partially 2-celled, 2-valved, many-seeded. [The best known genus, *Gentiana*, consists mainly of autumn-flowering species.]

I. OBOLARIA L.

A low, smooth, purplish-green perennial. Flowers axillary and terminal. Calyx of 2 distinct, spatulate, bract-like sepals. Corolla tubular-bell-shaped, 4-lobed. Stamens short, inserted at the notches of the corolla. Style short; stigma 2-lipped. Capsule ovoid, more or less 2–4-celled; seeds very minute and numerous.

1. O. virginica L. Pennywort. Stem 3–8 in. high, often several from the same root. Leaves somewhat fleshy, wedge-obovate or somewhat diamond-shaped, often truncate, sessile. Flowers opposite or terminal in threes, nearly sessile. Corolla pale purple or nearly white. Rich woodlands, among dead leaves.

II. MENYANTHES L.

Perennial, scape-bearing marsh herbs. Rootstock creeping. Leaves of 3 leaflets. Flowers racemed. Calyx 5-parted. Corolla fleshy, funnel-shaped, the limb 5-parted. Stamens 5, inserted on the corolla tube. Disk of 5 hypogynous glands. Ovary 1-celled; style thread-shaped; stigma 2-lobed. Capsule globose, many-seeded.

1. M. trifoliata L. Buck Bean, Marsh Trefoil. Rootstocks stout and matted. Leaflets obtuse, entire. Flowers $\frac{3}{4}$ in. in diameter, white or pinkish. Bogs, especially N.

81. APOCYNACEÆ. Dogbane Family

Trees, shrubs, or herbs, with milky juice, often climbing. Leaves usually opposite, rarely whorled, entire, nearly or quite without stipules. Flowers actinomorphic, solitary or in cymes. Calyx 4–5-cleft. Corolla hypogynous, funnel-, salver-, or bell-shaped, sometimes with scales in the throat. Stamens 4–5, borne on the corolla tube or throat; filaments very short;

anthers somewhat attached to the stigma. Ovary of 2 carpels, free or somewhat united; style short; stigma entire or 2-cleft. Fruit of 2 many-seeded pods (in the genera here described).

I. AMSONIA Walt.

Perennial herbs. Stems erect, branched. Leaves alternate. Flowers in terminal panicles. Calyx small, 5-parted. Corolla small, pale blue, funnel- or salver-form, downy within. Stamens inserted above the middle of the tube, included. Ovary of 2 carpels, united at the top by the slender style; stigma globose, surrounded by a cup-shaped appendage. Fruit 2 slender, erect, many-seeded follicles; seeds without tufts of hairs.*

1. A. Tabernæmontana Walt. AMSONIA. Stem smooth and glabrous, branched above, 2–3 ft. high. Leaves lanceolate, entire, acuminate at the apex, acute at the base, smooth above, with a bloom or slightly downy beneath, short-petioled. Flowers numerous, on bracted pedicels. Corolla tube slender, smooth or sometimes downy above; the lobes narrow, as long as the tube. Follicles slender, spreading, 4–6 in. long; seeds downy. Swamps and wet ground S.*

II. VINCA L.

Perennial herbs or small, slender shrubs; juice not perceptibly milky. Leaves evergreen. Flowers solitary, white, blue, or purple. Calyx 5-parted; lobes taper-pointed, glandular inside at the base. Corolla salver-shaped, thickened at the throat, 5-lobed. Stamens 5, inserted on the upper or middle part of the corolla tube. Ovary of 2 carpels. Pods 2, slender, cylindrical, many-seeded.

1. V. minor L. PERIWINKLE. Stem slender, trailing, often rooting at the nodes, 1–3 ft. long. Leaves ovate, acute at the apex, short-petioled, bright green. Flowers axillary, solitary, 1 in. wide. Calyx with linear lobes nearly as long as the inflated tube of the blue corolla. Matured pods slender, slightly divergent. Introduced from Europe and common in gardens.*

III. APOCYNUM L.

Perennial herbs. Stems with very tough bark, branched above. Leaves opposite, entire. Flowers in terminal and axillary bracted cymes. Calyx small, 5-parted, lobes acute.

Corolla bell-shaped, 5-lobed, with a small, scale-like appendage at the base of each lobe. Stamens 5, distinct, inserted on the base of the corolla tube. Ovaries 2, distinct, united by the styles; stigma obtuse, 2-lobed. Pods long, slender, many-seeded; seeds with a tuft of hairs.*

1. A. androsæmifolium L. Dogbane. Plant 2–3 ft. high, usually smooth, purplish, the branches spreading and forking. Leaves 2–3 in. long, acute, mucronate; petioles about $\frac{1}{4}$ in. long. Cymes mostly terminal, few-flowered. Calyx teeth lance-ovate, about half as long as the corolla tube. Corolla pale red or whitish, its lobes recurved. Pods stouter than in No. 2. Roadsides and clearings; common.

2. A. cannabinum L. Indian Hemp. Stem erect, smooth, with numerous erect or ascending branches. Leaves oval to oblong, mucronate at the apex, rounded at the base, downy beneath, short-petioled. Cymes terminal, compact, shorter than the leaves. Flowers are on short, bracted pedicels, greenish-white, about $\frac{1}{4}$ in. broad. Calyx lobes lanceolate, nearly as long as the tube of the corolla. Corolla lobes erect. Pods very slender, tapering, 3–4 in. long. Along fences and in thickets.*

IV. NERIUM L.

Shrubs. Leaves mostly whorled in threes. Flowers in terminal cymes. Calyx small, lobes acute. Corolla salverform, the throat of the tube crowned with cleft or cut-fringed scales. Stamens 5, short, included; anthers tipped with a hairy bristle. Ovary of 2 carpels; style short. Pods erect; seeds with a tuft of hairs.*

1. N. Oleander L. Oleander. Stem erect, diffusely branched from below, 4–10 ft. high. Leaves narrowly elliptical, acute at each end, thick and leathery, short-petioled. Flowers showy, in large clusters, red or white, often double; scales of the crown 3–4-pointed unequal teeth. Pods spindle-shaped, 3–4 in. long. Introduced from Palestine. Common in cultivation.*

82. ASCLEPIADACEÆ. Milkweed Family

Shrubs or herbs, often twining; juice usually milky. Leaves generally opposite or whorled, entire, without stipules. Flowers regular. Calyx 5-parted. Corolla 5-parted. Stamens 5; the filaments usually united around the styles, often with

hood-like appendages, each with an incurved horn borne on the stamen tube and forming a crown around the stigma (Fig. 27, *A*); anthers pressing against the lobes of the stigma; the pollen clinging together in tough, waxy or fine-grained

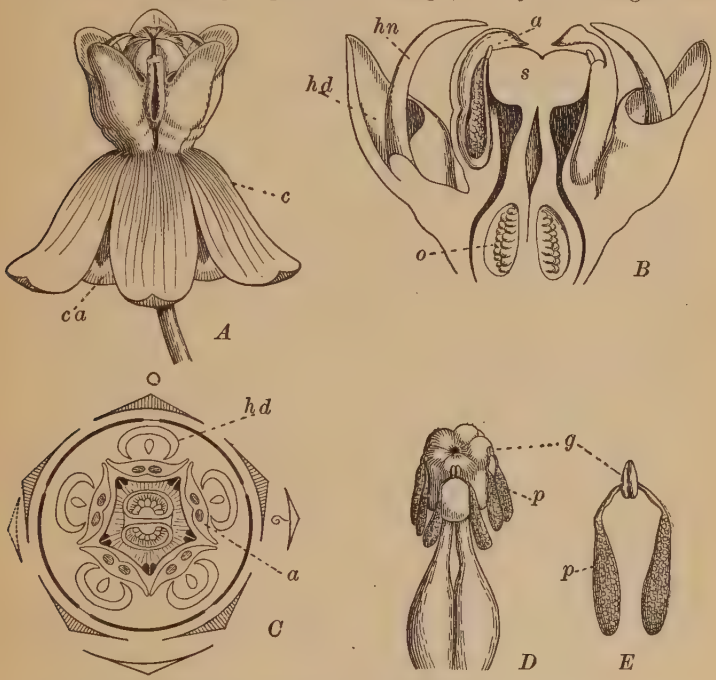


FIG. 27. Flower of *Asclepias syriaca*

A, entire flower; *B*, vertical section; *C*, diagram; *D*, details of pollen-masses and glands. *ca*, calyx; *c*, corolla; *hd*, hood; *hn*, horn; *a*, anther; *s*, stigma; *o*, ovary; *g*, gland; *p*, pollen-mass. (All considerably enlarged.)

masses. Ovary free from the calyx tube, of 2 carpels, more or less united below but unconnected above; styles 2; stigmas 5-angled; ovules several–many. Fruit consisting of 1 or 2 pods. The flowers are very highly specialized for pollination by insects (see below, under *Asclepias*).

I. ASCLEPIODORA Gray.

Plants much like *Asclepias*, but the hoods without horns. Lobes of the corolla ascending or spreading.

1. A. viridis Gray. Green Milkweed. Stems about 1 ft. high, nearly smooth. Leaves alternate, short-petioled, oblong to ovate-lanceolate. Umbels clustered. Flowers about 1 in. in diameter, green with a purplish crown. In dry soil W. and S.

II. ASCLEPIAS L.

Perennial herbs. Flowers in simple (usually many-flowered) umbels. Calyx small, 5-parted, its lobes reflexed. Corolla deeply 5-parted, with reflexed lobes; crown of hoods and horns conspicuous (Fig. 27, *A*, *B*). Stamens with their filaments united into a tube around the pistil and anthers attached to the stigma (Fig. 27, *D*, *E*); anther cells 2, each cell containing an elongated, pear-shaped, tough mass of pollen, a mass from one anther always paired with one from the adjoining anther and each two together suspended from one of the 5 split glands on the angles of the stigma (Fig. 27, *D*, *E*). Ovaries 2; styles very short. Pods 2 or sometimes 1 and the other undeveloped. Seeds flat, each with a tuft of long, silky hairs. The flowers are pollinated by insects, which get their feet entangled in the clefts of the glands (Fig. 27, *g*) and then carry off the pollen masses.

1. A. tuberosa L. Butterfly Weed, Pleurisy Root. Stems roughish-hairy, 1–2 ft. high. Juice not milky. Leaves abundant, linear to lanceolate-oblong. Flowers showy, usually bright orange, in terminal cymose umbels. Horns nearly erect and slender. Pods nearly erect, covered with fine down. In dry fields.

2. A. decumbens L. Reclining Butterfly Weed. Much resembling *A. tuberosa*, but the stems reclining with the ends erect. Leaves elliptic or oblong. Umbels racemed along the branches. In dry soil.

3. A. purpurascens L. Purple Milkweed. Stem 1–3 ft. high, somewhat branched above. Leaves 4–6 in. long, elliptical or nearly so, the upper ones taper-pointed, slightly velvety beneath, short-petioled. Umbels terminal. Flowers ½ in. long, dark purple; pedicels shorter than the peduncle; horn broadly scythe-shaped, with the point bent sharply inward. Dry soil.

4. A. syriaca L. Common Milkweed. Stem stout, 3–4 ft. high, finely downy. Leaves 4–8 in. long, oblong or nearly so, downy beneath. Umbels terminal or nearly so. Flowers varying from purple or greenish-purple to whitish, numerous, with a strong, sweet but sickening odor; hoods with a tooth on each side of the stout horn. Common in rich soil.

5. A. phytolaccoides Pursh. Poke-Leaved Milkweed. Stem rather slender, 3–5 ft. high. Leaves 6–9 in. long, ovate or oval-lanceolate, taper-pointed, short-petioled. Umbels several, mostly lateral; pedicels slender and drooping. Lobes of the corolla greenish; hoods white, with 2 teeth; horns with an awl-shaped point extending far out of the hoods. Damp thickets N. and E.

6. A. variegata L. White Milkweed. Stem stout, leafless and smooth below, leafy and downy in lines above. Leaves opposite, the middle ones sometimes in fours, petioled, ovate to obovate, cuspidate, smooth on both sides, pale beneath, edges slightly crenate. Umbels 1–5, compact, downy, 1–2 in. long; pedicels erect, as long as the peduncles. Corolla white, often purple at the base; hoods roundish, spreading, a little longer than the thick, awl-pointed, incurved horn. Dry, open woods E. and S.*

7. A. quadrifolia L. Four-Leaved Milkweed. Stem slender, 1⅓–2 ft. or more high, usually leafless below. Leaves in 1 or 2 whorls of 4 each, near the middle of the stem, and a pair or two opposite, thin, slender-petioled, 2–4 in. long, ovate-lanceolate, taper-pointed. Umbels usually 2, sometimes 1, with slender pedicels. Corolla lobes very pale pink or whitish; hoods white; horn short, stout, and bent inward. Dry woods and fence rows.

III. HOYA R. Br.

Shrubby, more or less climbing, smooth, tropical plants. Leaves fleshy. Calyx 5-cleft; corolla 5-lobed, wheel-shaped, its divisions thick and with a waxy look; crown of 5 spreading segments; pollen masses fastened by the bases.

1. H. carnosa R. Br. Wax Plant. Stems long and slender, rooting and trailing. Leaves oval or nearly so, thick, dark green. Flowers in close umbels, pink or whitish, the corolla lobes covered on the upper surface with minute projections. Cultivated from India as a house plant and in conservatories.

83. CONVOLVULACEÆ. Morning-Glory Family

Usually twining herbs or shrubs, often with milky juice. Leaves alternate (wanting in *Cuscuta*), without stipules.

Flowers variously clustered, rarely solitary, often large and showy. Sepals 5. Corolla hypogynous, regular, tubular, bell-shaped or funnel-shaped; its limb more or less 5-lobed or angled. Stamens 5, inserted on the corolla tube. Ovary usually 2–4-celled; style slender, 2–4-cleft; ovules 1 or 2 in each cell. Capsule 1–4-celled, 2–4-valved, or bursting open across the base.

I. IMPOMŒA L.

Annuals or perennials; stems often twining. Flowers showy. Calyx not bracted at the base, of 5 sepals. Corolla bell-shaped or funnel-shaped, twisted in the bud. Stamens not projecting from the corolla. Style slender; stigma knobbed, 2-lobed. Fruit a 2–3-celled capsule. [*I. purpurea*, the common morning-glory, blossoms too late for school study. *I. Batatas*, the sweet potato, seldom flowers.]

B. Fl. species 1 (*Quamlocit*).

1. I. Quamlocit L. Cypress Vine. Stem slender, smooth, twining high. Leaves dark green, pinnately cut, the divisions linear, smooth. Peduncles slender, as long as the leaves, 1–5-flowered; pedicels thickened upward. Sepals ovate or oblong, mucronate. Corolla bright scarlet, or sometimes yellowish-white, salverform; the tube 1–1½ in. long; the limb flat and spreading, ½–¾ in. wide. Capsule ovoid, twice the length of the sepals. Common in gardens.*

2. I. hederacea Jacq. Wild Morning-Glory. Stems hairy, twining. Leaves heart-shaped, 3-lobed. Peduncles 1–3-flowered. Calyx very hairy below. Corolla showy, bluish-purple or white. Pod usually 3-celled, with 2 seeds in each cell. A weed in fields and about dwellings. Introduced from tropical America.

3. I. pandurata G. F. W. Mey. Wild Potato Vine. Perennial, from a very large, tuberous root; stem trailing or twining, smooth or slightly downy, 5–10 ft. long. Leaves broadly heart-shaped, with the apex slender and obtuse, sometimes fiddle-shaped or 3-lobed; petioles slender. Peduncles longer than the petioles, 1–5-flowered. Sepals oblong, obtuse, smooth, mucronate, the 2 outer ones shorter. Corolla white with a purple throat, 2–3 in. wide, lobes pointed. Capsule globose, 2–3-seeded, the seeds woolly on the angles. On dry or damp sandy soil, along fences, railroad embankments, etc.; common S. and W.*

4. I. leptophylla Torrey. Bush Morning-Glory. Perennial. Stems smooth, much branched, erect, ascending or reclining, 2–4 ft.

long, from a huge root. Leaves 2–5 in. long, short-petioled, linear, acute. Peduncles short, 1–4-flowered. Sepals broadly ovate, obtuse. Corolla pink or purple, funnel-shaped, about 3 in. long. Pod ovoid, 2-celled. Plains W. and S.W.

II. CONVOLVULUS L.

Herbs or shrubs, with stems twining or nearly erect. Calyx not bracted, or inclosed in 2 large, leaf-like bracts. Corolla broadly funnelform or bell-shaped. Stamens not projecting from the corolla. Style 1; stigmas 2; ovary and pod 1–2-celled, 4-seeded.

1. C. spithamæus L. Downy, stem 6–12 in. high, erect or reclining. Leaves oblong, sometimes heart-shaped or eared at the base. Flowers white. Calyx inclosed by 2 large, oval, acutish bracts. Stigmas stout. In sandy soil.

2. C. repens L. Trailing Bindweed. Stems downy, 1–3 ft. long, trailing or twining. Leaves sometimes heart-shaped, often narrowly arrow-shaped, with the lobes at the base obtuse or rounded. Peduncles 1-flowered. Corolla white, or sometimes pink. Stigma ellipsoidal. Bracts beneath the calyx 2, ovate. In fields.

3. C. sepium L. Creepers, Rutland Beauty. Stem twining or sometimes extensively trailing. Leaves heart-arrow-shaped or somewhat halberd-shaped, the lobes at the base truncate. Flowers numerous and showy, white or tinged with rose color. Bracts at the base of the flower large, ovate, heart-shaped. Thickets and banks of streams, often cultivated.

4. C. arvensis L. Bindweed. A perennial, prostrate or climbing herb, with many stems, from a long, slender rootstock. Leaves very variable, more or less arrow-shaped, 1–3 in. long. Peduncles mostly 1-flowered; flowers white or pinkish, about ¾ in. long. Calyx not bracted. Stigmas linear. A weed in fields E.; adventive from Europe.

84. POLEMONIACEÆ. Phlox Family

Annual or perennial herbs, rarely shrubs. Leaves alternate or the lower opposite, without stipules. Flowers in terminal, forking cymes. Calyx hypogynous, 5-lobed. Corolla regular or nearly so, 5-parted. Stamens 5, inserted on the corolla tube, usually unequal. Ovary 3-celled; style simple; stigmas 3, linear; capsule 3-celled, the cells 1–many-seeded.

I. PHLOX L.

Perennial or rarely annual herbs; stems erect or diffuse. Leaves opposite, or the upper alternate, entire, without stipules. Flowers showy, white or purple, in terminal cymes or panicles. Calyx cylindrical or funnelform, 5-cleft, the lobes acute. Corolla salver-form, the tube long and slender, the limb 5-parted, the lobes spreading, entire or obcordate. Stamens included, unequal. Ovary 3-celled, style slender. Capsule ovoid, 3-celled, 1–few-seeded; seeds wingless or narrow-winged.*

1. P. paniculata L. Garden Phlox. Perennial; stems in clumps, stout, erect, simple or branched above, 2–4 ft. high. Leaves ovate-lanceolate to oblong, taper-pointed at the apex, rounded or cordate at the base, thin, smooth; veins prominent beneath. Cymes numerous and compact, forming a pyramidal panicle; pedicels short. Calyx teeth long, bristle-pointed. Corolla purple to white; lobes round-obovate, shorter than the tube. Capsule longer than the calyx tube. In rich woods; often cultivated.*

2. P. maculata L. Wild Sweet William. Stem erect, smooth or nearly so, rather slender, purple-spotted, 1–2 ft. high. Lower leaves lanceolate, the upper ones broader, taper-pointed, roundish or heart-shaped at the base. Panicle many-flowered, narrow, ellipsoidal. Calyx teeth lanceolate, hardly acute. Flowers purple, occasionally white. Damp woods and fields.

3. P. glaberrima L. Smooth Phlox. Stems smooth, slender, erect, 1–3 ft. high. Leaves narrowly lanceolate or linear, 1½–4 in. long, smooth except the rough and sometimes recurved margins. Cymes few-flowered, grouped in loose corymbs. Calyx teeth very narrow and sharp-pointed. Corolla pink or whitish, lobes longer than the tube. Prairies and open woods.

4. P. pilosa L. Downy Phlox. Perennial; stem erect, slender, simple or branched, 1–2 ft. high. Leaves linear-lanceolate to linear, distant, spreading, long, taper-pointed, sessile; stem and leaves downy. Cymes corymbose, loose. Flowers short-pediceled. Calyx glandular-viscid, the teeth shorter than the tube of the purple corolla, bristle-pointed. Corolla tube downy, lobes obovate. Capsule twice the length of the calyx tube. In dry, open woods.*

5. P. divaricata L. Wild Blue Phlox. Perennial; stems erect or ascending from a decumbent base, sticky-downy, 1 ft. high. Leaves distant, lanceolate to oblong, acute at the apex, rounded at the base, sessile, downy. Cymes corymbed, loosely flowered. Calyx teeth awl-shaped, longer than the tube. Corolla bluish-purple, ½–¾

in. long; lobes notched at the apex, as long as the tube. Capsule oval, shorter than the calyx teeth. In moist, open woods.*

6. P. Drummondii Hook. DRUMMOND'S PHLOX. Annual; stem erect or ascending, slender, weak, branching, glandular-downy, 6–12 in. high. Leaves mostly alternate, lanceolate to oblong, downy, the upper clasping by a heart-shaped base. Corymbs loose. Flowers rather long-pediceled. Calyx tube short, the teeth lanceolate, bristle-pointed, soon recurved. Corolla purple to crimson or white; orifice of the tube usually with a white or yellowish star-like ring; lobes rounded at the apex. Ovary 3-seeded; angles of the seeds winged. Introduced from Texas and common everywhere in gardens.*

7. P. subulata L. GROUND PINK, MOSS PINK, FLOWERING MOSS. Stems perennial, prostrate, 8–18 in. long, with many short, somewhat upright branches, 2–4 in. high. Leaves linear-awl-shaped, stiff, about ½ in. long, crowded, with clusters of smaller ones in their axils. Flower clusters 3–6-flowered. Corolla pink-purple, with a darker center, or sometimes white. Forms dense mats on rocky or sandy hillsides. S. and W. and often cultivated.

II. POLEMONIUM L.

Perennial herbs. Leaves alternate, pinnate. Flowers in corymbs. Calyx bell-shaped, 5-lobed. Corolla wheel-shaped, the limb with 5 obovate lobes. Stamens borne on the throat of the corolla, the filaments enlarged and hairy below. Capsule ovoid, 3-celled, many-seeded.

1. P. reptans L. JACOB'S LADDER, BLUE VALERIAN, BLUEBELL. Stems smooth, branched, and leaning over, 6–12 in. high. Leaflets usually 7 or 9, about an inch long. Corolla blue, about 3 times as long as the calyx. Capsule 3-seeded, borne on a short stalk in the persistent calyx. Damp, open woods, sometimes cultivated.

85. HYDROPHYLLACEÆ. WATERLEAF FAMILY

Herbs, usually hairy. Leaves commonly alternate and alternate-lobed. Flowers with their parts in fives, in appearance not unlike those of the following family, in one-sided cymes, which are coiled up at first. Calyx free from the ovary, usually with appendages at the notches. Corolla often with scales or nectar-bearing folds inside. Stamens borne by the corolla tube. Style 2-cleft, or styles 2. Ovary entire and usually 1-celled. Fruit a capsule, 2-valved, 4–many-seeded.

I. HYDROPHYLLUM L.

Coarse perennials. Leaves large, petioled. Flowers white or pale blue, inconspicuous. Calyx 5-parted, sometimes appendaged at the notches. Corolla bell-shaped, 5-cleft, with 5 double, nectar-bearing folds inside. Stamens projecting, the filaments bearded. Style projecting; ovary covered with bristly hairs, the placentæ very broad and fleshy, inclosing the ovules. Capsule globular, 1–4-seeded.

1. H. macrophyllum Nutt. A coarse, rough-hairy plant, about 1 ft. high, from scaly-toothed rootstocks. Leaves oblong, pinnate and pinnately cut, the divisions mucronate, obtuse, coarsely toothed. Flower cluster dense, globular, long-peduncled. Flowers about ½ in. long. Calyx little or not at all appendaged, its lobes broad at the base, but with slender, tapering points. Corolla white. Rich, rocky woods W. and S.

2. H. virginianum L. Nearly smooth, 1–2 ft. high, stem often forking at the base. Leaves of the stem mostly near the top, pinnately cut into 5–7 divisions; lobes oval-lanceolate, deeply serrate, the lowest ones distinct; petioles of the basal and lower leaves 4–8 in. long. Flower clusters on peduncles longer than the petioles of the upper leaves, from the axils of which or opposite which they arise. Flowers about ¼ in. long. Calyx not appendaged, its lobes narrowly linear, bristly-margined. Corolla whitish, with purplish veins. Moist woods.

3. H. appendiculatum Michx. Hairy, 1–1½ ft. high. Stem leaves palmately 5-lobed, the lobes acute, toothed, lowest ones pinnately divided. Flower cluster rather loose. Calyx appendaged at the notches. Corolla blue. Stamens projecting from the corolla little or not at all. Moist woods.

II. ELLISIA L. (MACROCALYX)

Delicate, branching annuals. Leaves pinnately lobed or divided. Flowers small, whitish. Calyx without appendages, 5-parted, enlarged and leafy in fruit. Corolla bell-shaped or cylindrical, little if any longer than the calyx, 5-lobed, with 5 minute appendages within the tube. Placentæ, fruit, and seeds nearly as in *Hydrophyllum*.

1. E. Nyctelea L. Plant somewhat roughish-hairy, 6–12 in. high. Leaves pinnately parted or divided. Peduncles 1-flowered, opposite the leaves. Corolla whitish. Pod globose, finally pendulous. In damp, shady places.

III. PHACELIA Juss.

Herbs, mostly annual. Leaves alternate, sometimes simple, but in most species lobed or divided. Flowers in one-sided clusters, often showy. Calyx 5-parted, without appendages. Corolla with 5 spreading lobes. Ovary 1-celled, with narrow placentæ.

1. **P. bipinnatifida** Michx. A hairy biennial. Stem upright, 1–2 ft. high. Leaves on long petioles, pinnately divided or deeply cut into 3–7 toothed or cut segments. Racemes long, loose, many-flowered. Flowers blue or violet, the spreading or recurved pedicels about as long as the calyx. Calyx segments linear. Corolla broadly bell-shaped, its appendages in pairs between the stamens. Rich soil in thickets and along streams.

2. **P. tanacetifolia** Benth. A tall, hairy annual. Leaves pinnately cut. Spikes long, densely flowered. Flowers showy, blue. Stamens projecting. Capsule 4-seeded. Cultivated from California.

3. **P. Whitlavia** Gray. WHITLAVIA. A rather coarse, sticky annual. Leaves broad, ovate, coarsely toothed, petioled. Flower clusters a loose raceme. Flowers showy, about 1 in. long, blue or sometimes white. Corolla bell-shaped. Stamens and style projecting. Capsule many-seeded. Cultivated from California.

4. **P. linearis** Holz. EUTOCA. A much-branched, somewhat rough or rough-hairy plant, 3–12 in. high. Leaves linear or lanceolate, entire or nearly so. Flowers showy, violet or white, loosely panicled. Capsule many-seeded. Cultivated from California.

86. BORAGINACEÆ. BORAGE FAMILY

Mostly herbs, with stems and foliage roughened with stiff hairs. Leaves alternate and entire, not aromatic. Flowers generally in a coiled inflorescence. Calyx 5-parted. Corolla hypogynous, generally 5-lobed and regular. Stamens 5, inserted on the corolla tube. Style 1; ovary commonly 4-lobed, ripening into 4 1-seeded nutlets.

I. HELIOTROPIUM L.

Herbs or low shrubs. Leaves petioled. Flowers white, blue, or lilac, in one-sided, curved spikes. Calyx 5-parted. Corolla salver-shaped, the throat open. Anthers almost sessile. Style short; stigma conical or knobbed. Fruit separating into 2 or 4 nutlets.

1. H. peruvianum L. Common Heliotrope. Somewhat shrubby, much branched. Leaves lance-ovate or somewhat oblong, veined and much wrinkled, short-petioled. Flowers numerous, in a cluster of terminal spikes, bluish-purple or lavender, very sweet-scented, the odor not unlike that of vanilla. Cultivated from Peru.

II. CYNOGLOSSUM L.

Coarse, rough-hairy or silky biennials. Flowers small, bluish-purple or white, in forked and usually bractless cymes. Calyx 5-parted. Corolla funnel-shaped, the mouth closed by prominent scales, its lobes obtuse. Stamens not projecting. Styles stiff, persistent. Nutlets 4, covered with hooked or barbed bristles, attached to a thickened, conical receptacle.

1. C. officinale L. Hound's-Tongue, Sheep Lice, Dog Bur, Stick-Tights. Stem 1–2 ft. high, soft-downy, panicled above. Basal leaves 8–10 in. long, long-petioled, oblong or oblong-lanceolate; stem leaves sessile, linear-oblong or lanceolate, rounded or heart-shaped at the base. Corolla ½ in. in diameter, reddish-purple. Nutlets ¼ in. long, with a thickened border. Whole plant with a strong smell like that of mice. A troublesome weed; along roadsides and in pastures; naturalized from Europe.

2. C. virginianum L. Wild Comfrey. Perennial. Stem stout, simple, erect, leafless above, 2–3 ft. high. Leaves oval or oblong, the upper clasping by a heart-shaped base. Racemes bractless; flowers pale blue, on short pedicels, which are recurved in fruit. Nutlets not margined, separating and falling away at maturity. On dry soil.

III. LAPPULA Moench.

Annual or biennial herbs, grayish, with rough hairs. Flowers small, blue or whitish, racemed or spiked. Corolla salver-shaped, its throat closed with 5 concave scales. Nutlets more or less covered with prickles, which are barbed at the tip, attached by their sides to the base of the style.

1. L. virginiana Greene. Beggar's Lice. A coarse biennial, 2–4 ft. high, the stem much branched above. Basal leaves roundish-ovate or heart-shaped, on slender petioles; stem leaves 3–4 in. long, pointed at both ends. Racemes 1–3 in. long, terminating the slender, spreading branches; flowers small, bluish-white. Fruit forming a troublesome bur. Fence rows and thickets.

IV. MYOSOTIS L.

Low, annual, biennial, or perennial herbs; stems branching, erect, or diffuse. Leaves alternate, entire. Flowers small, blue, pink, or white, in elongated, bractless racemes. Calyx 5-cleft, the lobes erect or spreading in fruit. Corolla salver-form, 5-lobed, the tube as long as the calyx, the throat with 5 small appendages. Stamens 5, inserted in the tube of the corolla, included. Ovary 4-parted; style slender. Nutlets smooth or downy, elliptical, compressed.*

1. M. scorpioides L. Forget-Me-Not. Perennial, from slender rootstocks; stems slender, downy, rooting at the nodes, 6–15 in. long. Leaves oblong to oblong-lanceolate, obtuse, narrowed to the sessile base, appressed-downy. Racemes many-flowered; pedicels becoming elongated in fruit. Lobes of the calyx shorter than the tube, spreading in fruit. Corolla blue, with a yellow eye. Nutlets angled, smooth. In gardens and often naturalized from Europe.*

2. M. laxa Lehm. Small Forget-Me-Not. Annual or perennial; whole plant downy; stem slender, weak, decumbent and rooting at the base, 1–2 ft. long. Lower leaves spatulate, the upper lanceolate. Racemes loosely flowered, becoming elongated in fruit; pedicels spreading. Calyx rough-hairy, the lobes as long as the tube. Corolla pale blue, with a yellow eye. Nutlets convex on all sides. On low ground and in brooks and ponds.*

V. MERTENSIA Roth.

Perennial herbs. Leaves generally pale, smooth, and entire. Calyx short, deeply 5-cleft or 5-parted. Corolla somewhat trumpet-shaped or funnel-shaped, often with 5 small folds or ridges in the throat, between the points of insertion of the stamens. Style long and slender. Nutlets smooth, or at length becoming wrinkled.

1. M. virginica Link. Lungwort, Bluebells. Smooth, nearly erect, 1–1½ ft. high. Basal leaves large, obovate or nearly so, and petioled; stem leaves smaller, sessile. Flowers clustered. Corolla nearly trumpet-shaped, varying with age from lilac to blue (or occasionally white). Stamens with slender filaments projecting beyond the corolla tube. Damp, open woods, and banks of streams; sometimes cultivated.

VI. LITHOSPERMUM L.

Herbs, with stout, usually reddish roots. Flowers appearing axillary and solitary or else in leafy-bracted spikes. Corolla funnel-shaped or salver-shaped, with or without folds or appendages at the mouth of the tube; the limb 5-cleft, its divisions rounded. Stamens included in the corolla tube, the anthers nearly sessile. Nutlets either smooth or wrinkled, generally very hard and bony.

1. L. arvense L. Corn Gromwell. A rough weed, about 1 ft. high. Leaves narrowly lanceolate. Flowers inconspicuous, whitish, in the upper leaf axils. Corolla hardly extending beyond the calyx, without appendages in the throat. Nutlets rough or wrinkled and dull. Sandy banks and roadsides; naturalized from Europe.

2. L. Gmelini Hitchc. Hairy Puccoon. Rough-hairy, perennial, 1–2 ft. high. Corolla deep orange-yellow, with appendages in the throat and clad with wool within at the bottom; flowers handsome, peduncled, in a crowded cluster. Dry, open pine woods, in sandy soil.

3. L. canescens Lehm. Puccoon, Indian Paint. Perennial; clothed with soft hairs, 8–12 in. high. Flowers axillary and sessile. Corolla appendaged, not woolly within, showy, orange-yellow. Banks and open woods.

4. L. angustifolium Michx. Narrow-Leaved Puccoon. Perennial; rough, 6–18 in. high, from a deep root. Leaves linear, sessile, acute or nearly so. Flowers pediceled in terminal leafy racemes of two kinds, the earlier showy, bright yellow, with a corolla tube an inch or more long; the latter much smaller, pale yellow, cleistogamous, fruiting abundantly. Pedicels of the cleistogamous flowers at length recurved. Nutlets ovoid, white, very smooth, slightly pitted. In dry soil W.

VII. ONOSMODIUM Michx.

Mostly rough-hairy perennial herbs. Leaves sessile, entire, with prominent veins. Flowers rather small, white, greenish or yellowish, in leafy one-sided spikes or racemes. Calyx 5-parted into linear divisions. Corolla tubular or tubular-funnelform, with 5 acute erect lobes. Stamens 5, perigynous, not projecting from the corolla tube. Style thread-like, decidedly projecting. Nutlets usually only 1 or 2, white, smooth and shining.

1. O. virginianum A. DC. Stems rather slender, 1–3 ft. high, covered with rough, stiff bristles. Leaves oblong or oblong-lanceolate,

the lower ones narrowed at the base. Corolla narrow, its lobes lance-awl-shaped, slightly bearded outside with long bristles. In dry thickets or on hillsides.

2. O. hispidissimum Mackenzie. Stem stout, upright, 1–4 ft. high, shaggy with long bristly hairs. Leaves from lanceolate to oblong, acute, 2–4½ in. long. Corolla rather broad, its lobes ovate-triangular or triangular-lanceolate, thickly hairy outside. Nutlets with a very short neck at the base. Rich soil along river banks and bottom lands.

VIII. ECHIUM L.

Herbs or sometimes shrubs, usually stout, coarse, and hairy. Leaves entire. Flowers white, reddish-purple or blue, in spiked or panicled racemes. Calyx 5-parted. Corolla tube cylindrical or funnel-shaped; the throat dilated; the limb with 5 unequal lobes. Filaments unequal, attached to the corolla below, projecting from the corolla. Style thread-like; stigma 2-lobed. Nutlets 4, ovoid or top-shaped, wrinkled.

1. E. vulgare L. Blue Thistle, Blue Weed, Blue Devils. Stems 1–3 ft. high, more or less erect, leafy, covered with stinging hairs. Root leaves lanceolate or oblong, petioled, 4–8 in. long; stem leaves sessile, acute, rounded at the base. Flowers showy, reddish-purple in the bud, changing to bright blue. A very troublesome weed, especially in fallow fields. Naturalized from Europe.

87. VERBENACEÆ. Verbena Family

Herbs, shrubs, or trees. Leaves opposite or whorled, without stipules. Flowers zygomorphic, in bracted cymes. Calyx hypogynous, cleft or toothed. Corolla hypogynous, tubular, usually more or less 2-lipped. Stamens usually 4 (2 long and 2 short), inserted on the corolla tube. Ovary usually 2–4-celled (in *Phryma* 1-celled), with the style springing from its summit.

I. VERBENA L.

Annual or perennial herbs. Leaves simple, opposite, serrate or pinnately lobed. Flowers in terminal spikes which become much elongated in fruit. Calyx tubular, 5-ribbed, 5-toothed. Corolla salverform or funnelform, the tube often curved, bearded in the throat, limb spreading, 5-lobed, often

somewhat 2-lipped. Stamens 4 (2 long and 2 short), rarely only 2, included. Ovary 2–4-celled, 2–4-ovuled; style slender, 2-lobed. Fruit 2–4 smooth or roughened, 1-seeded nutlets. [Several of the commonest species are tall, coarse herbs, which blossom too late for school study.]*

1. **V. officinalis** L. EUROPEAN VERVAIN. Annual; stem erect, slender, nearly or quite smooth, branching, 1–3 ft. high. Leaves ovate to obovate in outline, pinnately lobed or divided, narrowed and entire toward the base, downy beneath; petioles margined. Spikes several, very slender; flowers small, purple; bracts shorter than the calyx. In fields and waste places. Naturalized from Europe.*

2. **V. angustifolia** Michx. NARROW-LEAVED VERVAIN. Perennial, rough-hairy; stem simple, or branched below, from a creeping base, 1–2 ft. high. Leaves lanceolate to spatulate, obtuse and toothed at the apex, tapering to a sessile base. Spike peduncled, slender, close-flowered; bracts about the length of the calyx. Corolla purple, tube slightly curved, $\frac{1}{4}$ in. long. In dry, open woods.*

3. **V. bracteosa** Michx. Perennial; widely spreading or decumbent, hairy; stems 6–15 in. long, 4-sided, branching from the base. Leaves wedge-lanceolate, 3-cleft or pinnately cut, short-petioled. Spikes sessile, stout, with large bracts, the lower ones pinnately cut and longer than the flowers. Flowers small, purple. On prairies and waste ground.

4. **V. bipinnatifida** Nutt. Perennial; plant rough-hairy, producing suckers, erect, 6–18 in. high. Leaves with petioles, or the upper ones sessile, once or twice pinnately parted into oblong or linear divisions. Spikes stout, dense and solitary at the ends of the branches; bracts usually longer than the calyx. Corolla bluish-purple or lilac, less than $\frac{1}{2}$ in. in diameter. Dry plains and prairies W. and S.

5. **V. canadensis** Britton. WILD VERBENA. A slender-stemmed, somewhat reclining annual, 1 ft. or less in height. Leaves ovate or nearly so, wedge-shaped at the base, lobed and toothed or 3-cleft. Flowers showy, reddish-purple or lilac (seldom white), in a peduncled spike. Calyx teeth as long as or longer than the bracts. Corolla very slightly bearded in the throat. In dry prairie soil and open woods; also cultivated. [Other somewhat similar cultivated species are from Brazil.]

II. CALLICARPA L.

Shrubs. Leaves simple, petioled, opposite or whorled, glandular-dotted. Flowers in axillary cymes. Calyx 4-toothed or entire. Corolla funnelform, 4-cleft, actinomorphic. Stamens 4, equal, projecting. Ovary 4-ovuled; style slender; stigma knobbed. Fruit a 1–4-seeded berry.*

1. C. americana L. French Mulberry, Mexican Mulberry. Shrubs, with star-shaped glandular or scurfy down, widely branched, 3–8 ft. high. Leaves ovate to oblong, acute at each end, crenate-serrate, rough above, downy beneath, glandular-dotted; petioles slender. Cymes many-flowered, the peduncle as long as the petiole; pedicels short. Calyx cup-shaped, the teeth short. Corolla double the length of the calyx, blue. Fruit violet-purple, very conspicuous in autumn. Common in fields and thickets S.*

88. LABIATÆ. Mint Family

Mostly herbs, with square stems and opposite, more or less aromatic, leaves, without stipules. Flowers generally in cyme-like axillary clusters, which are often grouped into terminal spikes or racemes. Calyx tubular, usually 2-lipped, persistent. Corolla usually 2-lipped. Stamens 4 (2 long and 2 short) or only 2. Ovary free, with 4 deep lobes, which surround the base of the style. Fruit consisting of 4 nutlets, ripening inside the base of the calyx.

A

Stamens 4.

(*a*) Calyx 2-lipped.

Lips entire. Scutellaria, I

Lips toothed and cleft. Plants not aromatic. Prunella, IV

Lips toothed and cleft. Plants aromatic. Leaves extremely small. Thymus, IX

(*b*) Calyx not 2-lipped, or not much so.

Calyx tubular, 5–10-toothed. Stamens not projecting from tube of corolla. Marrubium, II

Calyx tubular, with 5 equal teeth. Stamens under upper lip of corolla. Nepeta, III

Calyx tubular, bell-shaped, with 5 awl-shaped teeth. Stamens not turned down after maturing. Lamium, V

Calyx top-shaped, with spreading spiny teeth. Leonurus, VI

Calyx as in V. Stamens turned down after maturing. Stachys, VII

B

Stamens 2. Salvia, VIII

I. SCUTELLARIA L.

Mostly slender herbs, not aromatic. Flowers solitary or in pairs, axillary or in terminal spikes or racemes. Calyx bell-shaped, 2-lipped, the upper part swollen into a helmet-shaped pouch; mouth of the calyx closed after flowering. Corolla tube long, naked inside. Stamens 4, the anthers meeting in pairs, hairy-fringed. Style with a very short upper lobe. [The species here described are not the commonest ones, but most of the others grow in damp soil and bloom later.]

1. S. serrata Andr. SKULLCAP. Stem not much branched, 1–3 ft. high. Stem leaves serrate, taper-pointed at both ends, ovate or nearly so. Racemes single, loose. Calyx rather hairy. Corolla 1 in. long, the lips of equal length. Woods.

2. S. pilosa Michx. HAIRY SKULLCAP. Stem more or less hairy, not much if at all branched, 1–3 ft. high. Leaves a few distant pairs, diamond-ovate, oblong-ovate, or roundish-ovate, scalloped, obtuse, the lower heart-shaped or nearly truncate at the base, with long petioles. Racemes short, few-flowered. Corolla $\frac{1}{2}$ in. long; tube whitish, lips blue, the lower one rather shorter. Open woodlands and dry soil.

3. S. integrifolia L. LARGE-FLOWERED SKULLCAP. Stem covered with fine, grayish down, usually unbranched, 1–2 ft. high. Leaves lance-oblong or nearly linear, mostly entire, obtuse, with very short petioles. Corolla 1 in. long, tube pale, lips large and spreading, blue. Dry ground.

4. S. parvula Michx. SMALL SKULLCAP. Perennial with necklace-like tuber-bearing rootstocks. Stems slender, minutely downy, 3–12 in. long, erect or spreading. Leaves varying from ovate to lanceolate, or the lower nearly round. Flowers solitary in the axils of the upper leaves. Corolla $\frac{1}{6}$–$\frac{1}{3}$ in. long, violet, downy. In moist, sandy soil.

II. MARRUBIUM L.

Perennial, downy, or woolly herbs. Whorls of flowers axillary; flowers small; bracts leaf-like. Calyx tubular, 5–10-toothed; teeth somewhat spiny. Corolla short; upper lip erect, lower spreading, 3-cleft, the middle lobe broadest. Stamens 4, not projecting. Lobes of the stigma short and blunt.

1. M. vulgare L. HOREHOUND. Stems somewhat reclining, stout, branching, leafy, 1–1½ ft. high. Leaves broadly ovate, heart-shaped or wedge-shaped at the base, scalloped, leathery and wrinkled. Whorls

of flowers dense. Calyx teeth hooked at the tip. Corolla ½ in. long, white. Cultivated from Europe as an herb (used in preparation of horehound candy) and somewhat naturalized.

III. NEPETA L.

Erect or prostrate herbs. Whorls of flowers axillary or terminal; flowers blue or white. Calyx tubular, 15-ribbed, 5-toothed. Corolla tube slender below, dilated at the throat, naked; upper lip notched or 2-cleft; lower lip 3-cleft, middle lobe large. Stamens 4, ascending under the upper lip, the upper pair longer. Lobes of the stigma awl-shaped.

B. Fl. species 2 (*Glecoma*).

1. N. Cataria L. Catnip. Stem grayish, downy, 2–3 ft. high, branched, very leafy. Leaves large, ovate-heart-shaped, deeply scalloped, serrate, white and downy beneath. Corolla about ½ in. long, whitish with purple dots. Naturalized from Europe; a common weed about dooryards.

2. N. hederacea Trevisan. Ground Ivy, Gill-over-the-Ground, Creeping Charley, Crow Victuals, Robin Runaway. Creeping. Leaves roundish, kidney-shaped, and crenate. Corolla bluish-purple, three times as long as the calyx. Common in damp places about houses and gardens. Naturalized from Europe.

IV. PRUNELLA L.

Perennials, with stems simple or nearly so, and sessile, 3-flowered flower clusters in the axils of kidney-shaped bracts, the whole forming a spike or head. Calyx tubular-bell-shaped, somewhat 10-ribbed; upper lip broad, 3-toothed, the teeth short; lower lip with 2 longer teeth. Upper lip of the corolla upright, arched, and entire; the lower spreading, reflexed, fringed, and 3-cleft. Stamens 4, reaching up under the upper lip, with the tips of the filaments 2-toothed; only one tooth anther-bearing.

1. P. vulgaris L. Self-Heal, Healall, Carpenter Weed. Leaves with petioles, ovate-oblong, either entire or toothed, often somewhat hairy. Corolla usually blue or bluish, somewhat longer than the brown-purple calyx. Open woods and fields everywhere.

V. LAMIUM L.

Annual or perennial hairy herbs. Calyx tubular-bell-shaped, 5-veined, with 5 awl-pointed teeth of nearly equal length.

Corolla with dilated throat, upper lip arched, middle lobe of the lower lip notched, the lateral lobes small, close to the throat of the corolla. Stamens 4, rising beneath the upper lip.

1. L. amplexicaule L. Henbit, Dead Nettle. An annual or biennial weed. Leaves roundish, deeply scalloped, the lower ones petioled, the upper sessile and clasping. Corolla sometimes $\frac{3}{4}$ in. long, downy, rose-colored or purplish. Not uncommon about gardens and dooryards. Naturalized from Europe.

2. L. purpureum L. Stem 6–18 in. high, silky-hairy or nearly smooth, reclining below, branched from the base. Leaves long-petioled, obtuse, heart-shaped, scalloped. Whorls of flowers mostly terminal, crowded. Corolla $\frac{1}{2}$–$\frac{3}{4}$ in. long, purple (rarely white). Naturalized from Europe.

VI. LEONURUS L.

Erect herbs. Leaves lobed. Whorls of flowers axillary, densely flowered, scattered; bractlets awl-shaped; flowers small, pink or white. Calyx 5-nerved, top-shaped, with 5 rather spiny, spreading teeth. Corolla with upper lip erect and entire, lower 3-cleft. Stamens 4; anthers joined in pairs. Nutlets with 3 projecting angles, their sides channeled.

1. L. cardiaca L. Motherwort. Stem 2–4 ft. high, prominently angled, stiff, stout, upright, very leafy. Leaves palmately lobed or cleft; basal ones long-petioled; lower stem leaves many-cleft, the upper ones 3-cleft, prominently nerved, the divisions acute. Corolla $\frac{1}{2}$ in. long, pale rose color, the upper lip and outside of the tube densely soft-bearded. Common about dooryards and fence rows. Naturalized from Europe.

VII. STACHYS L.

Herbs, rarely shrubs. Leaves scalloped or serrate. Whorls of flowers 2 or more flowered, usually in terminal racemes. Calyx nearly bell-shaped, 5-toothed. Corolla tube cylindrical, usually with a ring of hairs inside, not dilated at the throat; upper lip erect or spreading; lower spreading, 3-lobed, the middle lobe largest. Stamens 4, the 2 lower longest.

1. S. palustris L. Perennial; stem erect, 4-angled, 2–3 ft. high, hairy, especially on the angles, with projecting or reflexed hairs, leafy. Stem leaves short-petioled or sessile, ovate-lanceolate or oblong-lanceolate, scalloped-serrate, coarsely or finely downy, roundish

at the base, rather obtuse at the tip. Calyx bristly, the lance-awl-shaped teeth rather spiny. Upper lip of the corolla downy. In wet soil, especially N.

2. **S. tenuifolia** Willd., var. **aspera**. Taller than No. 1; angles of the stem covered with stiff reflexed bristles, but the sides often smooth. Leaves serrate, nearly all with distinct petioles. Calyx usually smooth. Corolla smooth throughout. Damp thickets and along streams.

VIII. SALVIA L.

Annual, biennial, or perennial herbs, or sometimes shrubby. Flowers in spikes, racemes, or panicles, usually showy. Calyx tubular or bell-shaped, not bearded in the throat, 2-lipped, the upper lip entire or 3-toothed, the lower 2-cleft. Corolla 2-lipped; the upper lip entire or notched, the lower spreading, 3-lobed, with the middle lobe longer. Stamens 2, short; anthers 2-celled, the upper cell fertile, the lower imperfect. Style 2-cleft. Nutlets smooth.*

1. **S. lyrata** L. Lyre-Leaved Salvia. Biennial or perennial; stem erect, sparingly branched above, rough-hairy, 1–2 ft. high. Leaves mostly basal, spreading, lyrate-pinnatifid, usually purple; stem leaves small, sessile or short-petioled. Racemes many-flowered, whorls about 6-flowered. Calyx teeth short on the upper lip, long and awl-shaped on the lower. Corolla blue or purple; the tube about 1 in. long, dilated upward. On dry soil.*

2. **S. officinalis** L. Garden Sage. Stem shrubby, slender, much branched below, 1 ft. high. Leaves grayish-green, lance-oblong, crenate, wrinkled. Flowers in terminal spikes, whorls several-flowered. Corolla blue, upper lip strongly arched, about equaling the lower. A common garden herb. Cultivated from Europe.*

IX. THYMUS L.

Small, much-branched shrubs, very aromatic. Leaves small, entire, margins often rolled under. Whorls of flowers few-flowered, in loose or close spikes; bracts very small; flowers usually purple. Calyx ovoid, 2-lipped; upper lip 3-toothed; lower 2-cleft, woolly in the throat. Corolla slightly 2-lipped. Stamens 4, usually projecting from the flower, straight; lower pair longer.

1. **T. Serpyllum** L. Creeping Thyme. Smooth or hairy, stem prostrate, the flowering branches somewhat ascending. Leaves $\frac{1}{8}$–$\frac{1}{4}$

in. long, flat, ovate or obovate-lanceolate, obtuse. Flowers crowded in spikes at the end of the branches. Corolla rose-purple, $\frac{1}{4}$–$\frac{3}{4}$ in. long. Naturalized from Europe.

2. **T. vulgaris** L. Garden Thyme. More erect than No. 1. Leaves somewhat curled under at the edges. Flower clusters shorter and not all terminal. Corolla pale purple. Cultivated from Europe as an herb.

89. SOLANACEÆ. Nightshade Family

Mostly tropical herbs or shrubs (rarely trees). Leaves usually alternate, without stipules. Flowers actinomorphic, borne on bractless pedicels at or above the leaf axils, or in cymes. Calyx hypogynous, 5-cleft, usually persistent. Corolla hypogynous, wheel-shaped, bell-shaped, or salver-shaped, 5-lobed. Stamens 5, short, inserted on the corolla tube. Ovary 2-celled or imperfectly 4-celled; style simple; stigma simple or lobed. Fruit a many-seeded capsule or berry.

I. SOLANUM L.

Herbs or shrubs; stems often prickly, sometimes climbing. Leaves alternate, often nearly or quite opposite. Flowers clustered, the peduncles often opposite or above the axils. Calyx spreading, 5-toothed or 5-cleft, persistent. Corolla wheel-shaped, 5-lobed. Stamens 5, projecting, the filaments very short, the anthers long and meeting about the style. Ovary 2-celled; style slender. Fruit a many-seeded, juicy berry.*

1. **S. Dulcamara** L. Bittersweet. Perennial; stems rather shrubby, long, and climbing. Leaves heart-shaped, or some of them with irregular lobes, or ear-like leaflets at the base. Flowers blue or purple, somewhat cymose. Berries showy, of many shades of orange and red in the same cluster, according to their maturity. Naturalized from Europe.

2. **S. nigrum** L. Nightshade. Annual; stem smooth, or downy with simple hairs, erect, diffusely branched; branches wing-angled, 1–3 ft. high. Leaves ovate, irregularly toothed or entire, somewhat inequilateral, petioled. Flowers in lateral, peduncled umbels, small, white, drooping. Calyx lobes obtuse; corolla $\frac{1}{3}$–$\frac{1}{2}$ in. wide; filaments downy; berries globose, smooth, black when ripe. Common in cultivated fields and waste places.*

3. S. carolinense L. HORSE NETTLE. Perennial; stem erect, branched, downy with star-shaped hairs, armed with straight yellow prickles, 1–3 ft. high. Leaves ovate-oblong, deeply toothed or lobed, acute at the apex, abruptly contracted to the short petiole, prickly on the veins. Racemes lateral, few-flowered; pedicels recurved in fruit. Calyx lobes taper-pointed. Corolla deeply angular-lobed, blue or white; berry globose, smooth, yellow. A common weed.*

4. S. rostratum Dunal. SAND BUR, BUFFALO BUR. Annual; the whole plant beset with yellow prickles; stem erect, diffusely branched, 1–2 ft. high. Leaves broadly oval or ovate in outline, deeply pinnately lobed or parted, petioled, downy with star-shaped hairs. Racemes few-flowered; pedicels erect in fruit. Calyx very prickly, becoming enlarged and inclosing the fruit. Corolla bright yellow, 5-angled, about 1 in. broad. From the West, becoming a troublesome weed in some places.*

5. S. tuberosum L. IRISH POTATO. Annual; stem diffusely branched, downy, underground branches numerous and tuber-bearing. Leaves irregularly pinnatifid and divided. Flowers in cymose clusters, white or purple, with prominent yellow anthers; pedicels jointed. Corolla 5-angled, ¾–1 in. broad. Fruit a globose, greenish-yellow, many-seeded berry, about ½ in. in diameter. Cultivated from Chile.*

II. LYCOPERSICUM Hill.

Annual; stem diffusely branched. Leaves pinnately divided. Flowers in raceme-like clusters on peduncles opposite the leaves. Calyx 5–many-parted, persistent. Corolla wheel-shaped, 5–6-parted. Stamens 5–6, inserted in the short tube of the corolla; filaments short, anthers elongated. Ovary 2–several-celled; style and stigma simple. Fruit a many-seeded berry.*

1. L. esculentum Mill. TOMATO. Stem diffusely branched, at length leaning over, furrowed and angled below, sticky-hairy, 3–5 ft. long. Leaves irregularly lobed and pinnatifid, petioled. Calyx lobes linear, about as long as the yellow corolla. Fruit (in the wild state) globose or ovoid, red or yellow, ¼–½ in. in diameter, but greatly enlarged in cultivation. Common in cultivation from tropical America.*

III. LYCIUM L.

Shrubs or woody vines, often spiny. Leaves entire, alternate, often fascicled. Flowers solitary or clustered, terminal

or axillary. Calyx persistent, 4–5-lobed or toothed, not enlarged in fruit. Corolla funnelform or bell-shaped, the limb 4–5-lobed, the lobes obtuse. Stamens 4–5, projecting. Ovary 2-celled; style single; stigma obtuse. Fruit a many-seeded berry.*

1. L. halimifolium Mill. MATRIMONY VINE. Stem slender, branching, twining or trailing, 6–15 ft. long; branches angled, spiny. Leaves elliptical, smooth, entire, sessile or short-petioled. Flowers solitary or few in the axils; peduncles long and slender. Corolla spreading, greenish-purple, $\frac{1}{3}$–$\frac{1}{2}$ in. wide. Berry oval, orange-red. Introduced from Africa, and often planted for covering trellises.*

IV. DATURA L.

Annual or perennial, strong-scented herbs; stems tall and branching. Leaves petioled, entire or lobed. Flowers large, solitary in the forks of the branches. Calyx tubular, 5-toothed or lobed, the upper part deciduous and the lower persistent. Corolla funnelform, 5-angled. Stamens 5, inserted in the corolla tube. Ovary 2-celled or imperfectly 4-celled; style filiform; stigma 2-lobed. Fruit a spiny, 4-valved, many-seeded capsule.*

1. D. Stramonium L. JIMSON WEED. Annual; stem smooth, green, stout, forking above, 1–4 ft. high. Leaves ovate to oblong-ovate, acute at the apex, narrowed at the base, sinuate-toothed, petioled. Calyx 5-angled. Corolla white, about 4 in. long. Capsule ovoid, erect, 2 in. long. A common weed; poisonous. Naturalized from Asia (?).*

2. D. Tatula L. Taller, with a purple stem; flowers rather later than No. 1. Corolla violet-tinged. Naturalized from tropical America.

V. PETUNIA Juss.

Herbs; leaves alternate and entire. Divisions of the calyx oblong-spatulate. Corolla showy, spreading, funnel-shaped, not perfectly actinomorphic. Stamens 5, somewhat unequal in length, inserted in the middle of the corolla tube and not projecting beyond it. Capsule 2-celled, containing many very small seeds.

1. P. violacea Lindl. COMMON PETUNIA. Stems rather weak and reclining. Leaves covered with clammy down. Corolla varying from pale pink to bright purplish-red, often variegated, with a broad, inflated tube, which is hardly twice as long as the calyx. Cultivated annual from South America.

2. P. nyctaginiflora Juss. White Petunia. Leaves somewhat petioled. Tube of corolla long and slender. Flowers white. Cultivated from South America. This and the preceding species much mixed by hybridization.

90. SCROPHULARIACEÆ. Figwort Family

Mostly herbs, with flowers not actinomorphic. Calyx free from the ovary and persistent. Corolla often 2-lipped. Stamens usually 2 long and 2 short, or only 2 in all, inserted on the corolla tube, often 1 or 3 of them imperfectly developed. Pistil consisting of a 2-celled and usually many-ovuled ovary, with a single style and an entire or 2-lobed stigma.

Corolla wheel-shaped, stamens 5. Verbascum, I
Corolla wheel-shaped or salver-shaped, nearly actinomorphic, stamens 2. Veronica, VI
Corolla 2-lipped, the mouth closed by a palate, tubular below, a spur at the base. Linaria, II
Corolla 2-lipped, the mouth closed by a palate, tubular below, a short, broad pouch at the base. Antirrhinum, III
Corolla decidedly 2-lipped.
  Stamens with anthers 2. Gratiola, V
  Stamens 4, with a fifth antherless filament. Pentstemon, IV
  Stamens 4, the anther cells unequal. Castilleja, VII
  Stamens 4, the anther cells equal. Pedicularis, VIII

I. VERBASCUM L.

Biennial; stem tall, erect. Leaves alternate. Flowers in spikes, racemes, or panicles. Calyx deeply 5-cleft. Corolla wheel-shaped, 5-lobed, the lobes nearly equal. Stamens 5, unequal, declined; some or all of the filaments bearded. Style flattened at the apex. Fruit a globose capsule; seeds roughened.*

1. V. Blattaria L. Moth Mullein. Stem erect, slender, simple or sparingly branched, smooth below, downy above, 2–4 ft. high. Leaves oblong to lanceolate, acute at the apex, obtuse or truncate at the base, dentate to pinnately lobed, the lower petioled, the upper

sessile and clasping. Raceme long and loose, glandular-downy; pedicels bracted. Corolla white or yellow, marked with brown on the back, about 1 in. wide. Filaments all bearded with purple hairs. Capsule longer than the calyx. Common in fields and waste places. Naturalized from Europe.*

II. LINARIA Hill

Herbs, rarely shrubby. Lower leaves opposite, whorled or alternate. Flowers in bracted racemes or spikes, or axillary and solitary. Calyx 5-parted. Corolla 2-lipped, the tube spurred. Stamens 4, with sometimes a rudiment of a fifth. Stigma notched or 2-lobed. Capsule ovoid or globose; cells nearly equal.

1. L. vulgaris Hill. Butter and Eggs, Jacob's Ladder, Wild Flax. A perennial, erect, smooth herb, with a bloom; stem 1–2 ft. high. Leaves linear or lanceolate, 1–3 in. long, often whorled. Racemes densely flowered. Sepals shorter than the spur. Corolla yellow, $\frac{3}{4}$–1 in. long; spur parallel to and as long as the tube; throat closed by a palate-like fold. Common in dry fields and pastures and along roadsides. Naturalized from Europe.

2. L. canadensis Dumont. Toadflax. Biennial; flowering stems erect, slender, rarely branched, smooth, 1–2 ft. high; sterile stems prostrate, with opposite or whorled leaves, 2–6 in. long. Leaves linear, entire, sessile. Racemes erect, slender; pedicels erect, as long as the calyx. Corolla small, blue and white, the spur thread-like, curved, longer than the pedicels. Capsule 2-valved, the valves 3-toothed. On dry or cultivated ground E.

III. ANTIRRHINUM L.

Annual or perennial herbs. Leaves entire, rarely lobed, the lower ones opposite, the upper alternate. Flowers axillary and solitary, or racemed and bracted. Calyx 5-parted. Corolla 2-lipped; the tube with a sac, the broad-bearded palate closing the throat. Stamens 4. Stigma with 2 short lobes. Capsule 2-celled, the upper cell opening by 1 pore, the lower by 2.

1. A. majus L. Snapdragon. Perennial; stem erect, smooth below, glandular-downy above, 1–2 ft. high. Leaves linear to oblong-lanceolate, entire, smooth, sometimes fleshy, sessile or short-petioled. Flowers in a terminal raceme; pedicels short, stout, erect in fruit. Corolla $1\frac{1}{2}$–2 in. long, of many colors. Capsule oblique, the persistent base of the style bent forward. Common in gardens; cultivated from Europe, and often escaped.*

IV. PENTSTEMON Mitchell

Perennials, the stems branching from the base, unbranched above. Leaves opposite. Flowers usually showy, in a terminal panicle. Calyx of 5 nearly distinct sepals. Corolla tubular, the tube wide above and narrowed below; 2-lipped. Stamens 4 (2 long and 2 short), with a fifth antherless filament as long as the others, its upper half bearded. Capsule ovoid, acute.

1. P. hirsutus Willd. Stem somewhat sticky-downy, 1–2 ft. high. Leaves varying from oblong to lanceolate, 2–4 in. long, usually with small teeth. Flower cluster narrow. Corolla dingy violet, purplish, or whitish; the tube not much widened above, its throat nearly closed by a hairy palate. Sterile filament much bearded. Dry hillsides or stony ground.

2. P. gracilis Nutt. Slender Beardtongue. Stem 6–18 in. high, smooth below but the flower cluster covered with glandular, sticky hairs. Basal leaves spatulate or oblong; stem leaves most of them linear-lanceolate. Corolla purple or whitish, $\frac{3}{4}$–1 in. long, the tube enlarged above and its throat entirely open. Sterile filament bearded above along half its length. On moist prairies W.

3. P. lævigatus Ait. Stem usually smooth except the flower cluster, 2–4 ft. high. Leaves shining, those of the stem ovate-lanceolate or broadly lanceolate, 2–5 in. long, with a somewhat heart-shaped, clasping base. Flower cluster broader than in No. 1. Corolla white or oftener purplish, suddenly widened above, the throat not closed. Sterile filament slightly bearded toward the top. In rich soil.

4. P. Digitalis Nutt. Much resembling No. 3, but taller, sometimes 5 ft. high. Corolla white, the tube abruptly widened. In fields and thickets; sometimes cultivated.

5. P. barbatus Roth. Stems slender and rod-like, 3–4 ft. high. Leaves lanceolate, entire. Flower cluster long and loosely flowered. Flowers showy, drooping. Corolla tube slender, scarlet, somewhat bearded in the throat. Sterile filament beardless. Cultivated from Mexico.

V. GRATIOLA L.

Low herbs, growing in wet or damp ground. Leaves opposite, sessile. Flowers axillary and solitary, peduncled. Calyx 5-parted, usually with 2 bractlets at the base. Corolla somewhat 2-lipped. Perfect stamens 2. Stigma enlarged or 2-lipped. Pod 4-valved, many-seeded.

1. G. virginiana L. Stem cylindrical, 4–10 in. long, branching from the base. Leaves ¾–1½ in. long, varying from lance-oblong to spatulate. Corolla pale yellow, tinged with red. Common in muddy soil, along brooksides, etc.

VI. VERONICA L.

Herbs or shrubs. Lower leaves or all the leaves opposite, rarely whorled. Flowers in axillary or terminal racemes, rarely solitary. Calyx usually 4-parted. Corolla wheel-shaped or somewhat bell-shaped; limb usually 4-cleft, spreading, the side lobes commonly narrower. Stamens 2, inserted on the corolla tube at the sides of the upper lobe, projecting. Stigma somewhat knobbed. Capsule generally flattened, often notched at the apex, 2-celled, few–many-seeded.

1. V. americana Schwein. Brooklime. A perennial, smooth herb, somewhat prostrate below but the upper parts of the stem erect, 8–15 in. high. Leaves 1–2 in. long, lance-ovate or oblong, serrate, short-petioled. Racemes 2–4 in. long, axillary and opposite. Corolla wheel-shaped, blue. Capsule swollen, roundish. Muddy soil about springs and brooks.

2. V. officinalis L. Common Speedwell, Gypsy Weed. Perennial. Roughish-downy, with the prostrate stems spreading and rooting. Leaves wedge-oblong or nearly so, obtuse, serrate, somewhat petioled. Racemes dense, of many pale bluish flowers. Capsule rather large, inversely heart-shaped and somewhat triangular. Dry hillsides, open woods and fields.

3. V. serpyllifolia L. Thyme-Leaved Speedwell. Perennial; smooth or nearly so; branching and creeping below, but with nearly simple ascending shoots, 2–4 in. high. Leaves slightly crenate, the lowest ones petioled and roundish, those farther up ovate or oblong, the uppermost ones mere bracts. Raceme loosely flowered. Corolla nearly white or pale blue, beautifully striped with darker lines. Capsule inversely heart-shaped, its width greater than its length. Damp, grassy ground; a common weed in lawns.

4. V. peregrina L. Purslane Speedwell. A homely, rather fleshy, somewhat erect-branched annual weed, 4–9 in. high. Lowest leaves petioled, oblong, somewhat toothed; those above them sessile, the uppermost ones broadly linear and entire. Flowers solitary, inconspicuous, whitish, barely pediceled, appearing to spring from the axils of the small floral leaves. Corolla shorter than the calyx. Capsule roundish, barely notched, many-seeded. Common in damp ground, in fields and gardens.

VII. CASTILLEJA Mutis.

Herbs parasitic on the roots of other plants. Leaves alternate; the floral ones usually colored at the tip and more showy than the flowers. Flowers yellow or purplish in terminal leafy spikes. Calyx tubular, flattened, 2–4-cleft. Corolla tube included within the calyx; upper lip of the corolla very long, linear, arched, and inclosing the stamens, 2 of which are long and 2 short. Ovary many-ovuled.

1. C. coccinea Sprengel. SCARLET PAINTED CUP, PAINT BRUSH, INDIAN PINK, PRAIRIE FIRE, WICKAKEE. A hairy, simple-stemmed herb, annual or biennial. Root leaves clustered, obovate or oblong; stem leaves cut; floral leaves 3–5-cleft and bright scarlet (occasionally yellow) toward the tips, as though dipped in a scarlet dye. Calyx nearly as long as the pale yellow corolla, 2-cleft. The spikes are often very broad, making this one of the most conspicuous of our native flowers. Damp, sandy ground, or on bluffs near streams; sometimes in marshes.

2. C. sessiliflora Pursh. DOWNY PAINTED CUP. Perennial; stem leafy, 6–15 in. high, covered with ash-colored down. Lowest leaves linear and entire, upper ones usually deeply cleft into narrow segments; floral leaves green, like the upper stem leaves. Calyx lobes more deeply cleft on the lower than on the upper side, linear-lanceolate. Corolla yellowish, nearly 2 in. long; upper lip about twice the length of the lower one. On prairies W. and S.W.

VIII. PEDICULARIS L.

Perennial herbs, with the lower leaves pinnately cut and the floral ones reduced to bracts. Flowers spiked. Corolla markedly 2-lipped; the upper lip much flattened laterally and arched, the lower lip spreading, 3-lobed. Stamens 4, beneath the upper lip. Capsule 2-celled, tipped with an abrupt point, several-seeded.

1. P. canadensis L. COMMON LOUSEWORT. Hairy, with clustered simple stems, 1 ft. high or less. Leaves petioled, the lowermost ones pinnately parted, the others somewhat pinnately cut. Spike short, closely flowered, and leafy-bracted. Calyx split down the front. Corolla greenish-yellow and purplish, with its upper lip hood-like, curved under, and with 2 awl-like teeth near the end. Capsule flat, broadly sword-shaped. Knolls and openings among thickets.

91. BIGNONIACEÆ. Bignonia Family

Trees or shrubs, often twining or climbing, rarely herbs. Leaves usually opposite, without stipules. Flowers showy, zygomorphic. Corolla tubular, with a widened throat and a 5-lobed limb. Stamens usually 2 long and 2 short, or only 2. Ovary free from the calyx, 2-celled or rarely 1-celled, with many ovules. Fruit a capsule; seeds large, winged.

I. TECOMA Juss.

Woody vines, climbing by aërial rootlets. Leaves compound, odd-pinnate. Flowers large, in terminal clusters. Calyx bell-shaped, unequally 5-toothed. Corolla funnelform, enlarged above the calyx, 5-lobed, slightly 2-lipped. Stamens 4, 2 long and 2 short. Capsule slender, spindle-shaped, slightly compressed contrary to the partition, 2-valved, dehiscent. Seeds winged.*

1. T. radicans Juss. Trumpet Flower, Trumpet Creeper. Stems climbing high by numerous rootlets; bark shreddy. Leaves deciduous, petioled; leaflets 9–11, ovate to ovate-lanceolate, serrate, short-stalked, smooth or slightly downy. Flowers in short, terminal racemes or corymbs. Calyx tubular, ¾ in. long. Corolla 2–3 in. long, scarlet without, yellow within, the lobes spreading. Capsule 5–6 in. long, curved, often persistent through the winter. Seeds broadly winged. On borders of fields and in woods S.; often cultivated.*

II. CATALPA Scop.

Small trees. Leaves large, opposite, simple, petioled, deciduous. Flowers large and showy, in terminal panicles. Calyx irregularly 2-lipped. Corolla tubular-bell-shaped, oblique, 5-lobed, 2-lipped. Fertile stamens 2, sterile stamens 3, short. Fruit a linear, 2-valved, many-seeded capsule. Seeds winged.*

1. C. bignonioides Walt. Catalpa. A small tree with thin, rough gray bark, and light, soft but exceedingly durable wood. Leaves long-petioled, heart-shaped, entire or palmately 3-lobed, taper-pointed at the apex, palmately veined, downy. Branches of the panicle in threes; flowers large, 1–1½ in. long, white, variegated with yellow and purple. Corolla lobes undulate or crisped. Capsule

very slender, 1 ft. or more in length, pendulous. Seeds with long fringed wings. On margins of rivers and swamps S.; often cultivated.*

2. C. speciosa Warder. CATALPA. A tall tree with very durable wood. Leaves large, heart-shaped, taper-pointed. Corolla about 2 in. long, almost white, but slightly spotted; tube inversely conical; limb somewhat oblique, its lower lobe notched. Pod rather stout. Rich, damp woods, especially S. W.; often cultivated.

III. BIGNONIA L.

Woody vines. Leaves opposite, compound, usually tendril-bearing. Flowers large, in axillary clusters. Calyx cup-shaped, truncate, or undulate-toothed. Corolla spreading-tubular, somewhat 2-lipped, the lobes rounded. Stamens 4, 2 long and 2 short. Capsule linear, flattened parallel with the partition, the two valves separating from the partition at maturity; seeds flat, broadly winged.*

1. B. capreolata L. CROSS VINE. Stem climbing high, a transverse section of the older stems showing a conspicuous cross formed by the 4 medullary rays; branches smooth. Leaves evergreen, petioled; leaflets 2, ovate, taper-pointed with a blunt apex, heart-shaped at the base, entire, stalked; upper leaflets transformed into branching tendrils. Flowers numerous, short-peduncled. Corolla 2 in. long, reddish-brown without, yellow within. Capsule 6 in. long, flat, the valves with a prominent central nerve; seeds broadly winged on the sides, short-winged on the ends. Common in woods S.*

92. OROBANCHACEÆ. BROOM RAPE FAMILY

Leafless brownish root parasites; rootstock often tuberous, naked or scaly; stem usually stout, solitary, scaly. Flowers spiked or racemed. Sepals 4–5, free from the ovary. Corolla hypogynous, not actinomorphic, the tube curved, the limb 2-lipped. Stamens 4 (2 long and 2 short), inserted on the corolla tube; anthers 2-celled, the cells spurred at the base. Ovary 1-celled, of 2 carpels; style simple; stigma 2-lobed; ovules many. Capsule 1-celled, 2-valved, few–many-seeded; seeds very small.

I. CONOPHOLIS Wallr.

Stems often clustered, stout, covered with scales which overlap, the uppermost ones each with an axillary flower,

thus forming a spike. Calyx irregularly 4–5-cleft, split down the lower side. Corolla swollen below, decidedly 2-lipped, the upper lip arched. Stamens projecting.

1. C. americana Wallr. Squawroot, Cancer Root. Stems 3–6 in. high, yellowish or yellowish-brown. Flowers numerous, inconspicuous. Corolla dirty white or pale brown. In oak woods; not very common.

II. OROBANCHE L. (THALESIA)

Brownish or whitish plants, with naked scapes borne on scaly, mostly underground, stems. Calyx regular, 5-cleft. Corolla 5-lobed, slightly irregular. Stamens not projecting from the corolla tube.

1. O. uniflora L. One-Flowered Cancer Root. Slightly covered with clammy down. Stems very short-branched, each with 1–3 1-flowered scapes 3–5 in. high. Calyx lobes lance-awl-shaped, half as long as the corolla. Corolla yellowish-white, veiny, purple-tinged; palate with 2 yellow bearded ridges. Damp woods.

2. O. fasciculata Nutt. Stem scaly, upright, 3–4 in. high above ground and generally longer than the numerous 1-flowered peduncles. Calyx lobes short, triangular. Parasitic on wild species of *Artemisia*, etc., in sandy and loamy soil N.W. and W.

93. ACANTHACEÆ. Acanthus Family

Herbs or shrubs. Leaves opposite or whorled, without stipules. Flowers zygomorphic, usually with large bracts. Calyx of 4 or 5 unequal segments which considerably overlap each other. Corolla 4–5-parted and usually more or less 2-lipped. Stamens usually 2 long and 2 short, sometimes only 2. Ovary free from the calyx. Fruit usually a capsule. Seeds not winged. A large family, mostly tropical, with only a few insignificant wild species in the northern United States.

I. DIANTHERA L.

Perennial herbs; stem smooth. Leaves opposite, entire or toothed. Flowers axillary, solitary or clustered, zygomorphic. Calyx 5-parted. Corolla 2-lipped; upper lip erect, concave, entire or notched; the lower prominently veined, spreading,

3-lobed. Stamens 2, inserted in the throat of the corolla. Ovary 2-celled, 4-ovuled; style simple, acute. Capsule flattened, narrowed below into a little stalk.*

1. D. americana L. WATER WILLOW. Stem erect, slender, 2–3 ft. high. Leaves lanceolate to linear-lanceolate, taper-pointed at the apex, narrowed below to the sessile or short-petioled base. Flowers bracted, in short spikes, on peduncles as long as the leaves. Corolla pale blue or purple, the tube as long as the lips, lower lip wrinkled. Capsule about the length of the calyx. In water, S.*

II. RUELLIA L.

Perennial herbs; stems swollen at the joints and often between them, somewhat 4-angled. Leaves sessile or short-petioled, mostly entire. Flowers axillary, solitary or clustered, showy, white, blue, or purple. Calyx 2-bracted, 5-parted, the divisions linear and awl-shaped. Corolla tube slender, often much elongated, the limb spreading, nearly equally 5-lobed. Stamens 4 (2 long and 2 short), included or slightly projecting. Style slender. Capsule slender, narrowed below, 4–12-seeded.*

1. R. ciliosa Pursh. HAIRY RUELLIA. Stem erect, rather stout, often few-branched above, covered with white hairs, 4–30 in. high. Leaves oblong to ovate, acute or obtuse at the apex, narrowed and mostly sessile at the base, hairy-fringed. Flowers pale blue, solitary or 2–3 together. Calyx lobes bristle-shaped, half the length of the corolla tube. Tube of the corolla 2 in. long. Capsule shorter than the calyx, smooth, 8–12-seeded. A very variable species, the flowers often without a corolla. In dry woods and fields S.*

2. R. strepens L. SMOOTH RUELLIA. Stem erect, slender, usually simple, smooth or hairy, 1–3 ft. high. Leaves ovate to oblong, acute at the apex, narrowed below into a short petiole. Flowers solitary or in small clusters, sessile or short-peduncled. Calyx lobes shorter than the tube of the corolla, downy or fringed. Corolla blue, the tube 1½–2 in. long, the limb 1–1½ in. wide. Capsule usually longer than the calyx, smooth, 8–12-seeded. The later flowers often without a corolla. On rich, dry soil.*

94. PLANTAGINACEÆ. PLANTAIN FAMILY

Annual or perennial scape-bearing herbs. Leaves usually all basal, with parallel ribs. Flowers small, green, usually

spiked, regular and bisexual (Fig. 28). Sepals 4, persistent. Corolla hypogynous, salver-shaped, thin and dry; lobes 4, spreading. Stamens 4, usually inserted on the corolla tube; filaments thread-like; anthers large and versatile. Ovary free, usually 2–4-celled; style thread-like. Fruit a 1–4-celled, 1 or more seeded membranous capsule, which splits open transversely, the top coming off like a lid.

FIG. 28. Flowers of plantain (*Plantago lanceolata*), six times natural size

A, earlier stage, pistil mature, stamens not yet appearing outside the corolla; *B*, later stage, pistil withered, stamens mature

PLANTAGO L.

Characteristics of the genus as given above for the family.

1. P. major L. PLANTAIN. Perennial, from a very short rootstock. Leaves ovate to oval, strongly 5–9-ribbed, acute or obtuse at the apex, rounded at the base into a long, concave petiole, entire or toothed, smooth or slightly downy. Scape taller than the leaves, downy, spike densely flowered; bracts short, ovate. Flowers perfect. Stamens 4, projecting. Capsule ovoid, about twice the length of the calyx, 5–16-seeded; seeds angled and with a netted outer coat. Common in dooryards.*

2. P. Rugelii Decaisne. Leaves as in *P. major*, but smaller and thinner. Spikes less dense, usually drawn out to a slender point. Capsule 4–10-seeded; seeds oval, the outer coat not netted. In fields, woods, and waste ground.

3. P. lanceolata L. RIB GRASS. Biennial or perennial; soft-hairy or nearly smooth. Leaves numerous, lanceolate to elliptical, acute, long-petioled, strongly 3–5-ribbed, entire or toothed. Scapes much longer than the leaves, striate-angled, 1–2 ft. high; spike short and dense. Bracts and sepals ovate. Corolla smooth. Capsule longer than the calyx, 2-seeded. Naturalized from Europe; common in meadows.*

4. P. Purshii R. & S. Annual. White-woolly or silky. Scapes slender; leaves linear, usually 3-nerved; spikes dense, cylindrical, and very woolly; bracts stiff, as long as the flowers or slightly longer. Capsule 2–4-seeded, somewhat longer than the calyx. On dry prairies and plains W. and S.W.

5. P. aristata Michx. Large-Bracted Plantain. Annual. Leaves broadly linear, entire or sparingly and finely toothed, narrowed below into a margined petiole, smooth or silky-downy. Scape longer than the leaves, 6–10 in. high; spike dense. Bracts linear, ½–1 in. long. Stamens 4. Capsule 2-seeded, longer than the calyx. Common on dry soil.*

6. P. heterophylla Nutt. Many-Seeded Plantain. Annual. Leaves linear, fleshy, entire or with a few spreading teeth, smooth or slightly downy. Scapes slender, 3–6 in. high; spike very slender, many-flowered, the lower flowers often scattered. Bracts ovate, longer than the sepals. Stamens 2. Capsule twice the length of the calyx, many-seeded. Common in cultivated ground, especially S.*

95. RUBIACEÆ. Madder Family

Herbs, shrubs, or trees. Leaves opposite and entire, with stipules between them, or appearing whorled since the stipules resemble the leaves. Flowers epigynous, always bisexual, frequently dimorphous (as in *Houstonia*, *Mitchella*, and *Bouvardia*). Limb of the calyx 3–6-toothed. Corolla regular, inserted on the calyx-tube, as many-lobed as the calyx. Stamens equal in number to the divisions of the corolla. Ovary 2 or more celled. A very large and important family, of which many of the noteworthy species, for instance the coffee shrub and the cinchona tree, are natives of warm or tropical climates.

I. GALIUM L.

Annual or perennial herbs; stems slender, 4-angled. Leaves appearing whorled. Flowers small, in axillary or terminal cymes or panicles, bisexual or rarely dicœcious. Calyx tube short, the teeth minute or wanting. Corolla wheel-shaped, 3–4-lobed. Stamens 3–4, short. Ovary 2-celled; styles 2, short, united below. Fruit 2 united, sometimes fleshy, 1-seeded carpels, which do not split open.*

1. G. Aparine L. Goose Grass. Annual; stem weak, decumbent, sharply 4-angled and with backward-pointing prickly hairs, widely branched, 2–4 ft. long. Leaves 6–8 in a whorl, oblanceolate, prickly-hairy on the margins and midrib. Peduncles axillary, longer than the leaves, 1–3-flowered; flowers white. Fruiting pedicels erect; fruit dry, covered with hooked bristles. In waste places.*

2. G. circæzans Michx. Wild Licorice. Perennial; stems several, erect, smooth or downy, 12–18 in. high. Leaves 4 in a whorl, oval to ovate, obtuse at the apex, strongly 3-nerved, downy. Cymes long-peduncled, repeatedly branched. Flowers nearly sessile, greenish-purple; pedicels at length recurved. Fruit with hooked bristles. In dry, open woods S. Easily recognized by the sweet, licorice-like taste of the leaves.*

3. G. boreale L. Northern Bedstraw. Perennial; stem smooth, erect, 1–2 ft. high. Leaves in fours, linear-lanceolate, 3-nerved. Flowers bright white, in compact cymes, grouped in a dense panicle. Fruit usually with minute bristles. In rocky soil along banks of streams, especially N.

4. G. concinnum T. & G. Shining Bedstraw. Stems slender, smooth, shining, commonly much branched, 6–12 in. high, often with the angles minutely roughened. Leaves usually in sixes, linear or nearly so, often slightly cuspidate. Flowers small, white, in open cymes. Fruit small, smooth. Dry hills and woodlands.

5. G. asprellum Michx. Rough Bedstraw. Perennial; stem branching, weak, 3–5 ft. long, often reclining on bushes, with many hooked prickles directed backwards. Leaves usually in sixes, or on the branches in fours or fives, narrowly oval to lanceolate or oblanceolate, cuspidate, with midribs and margins almost prickly. Flowers white, in several–many-flowered cymes. Fruit smooth. In rich, moist soil.

6. G. triflorum Michx. Perennial; stems reclining or prostrate, angles rough-bristly. Leaves mostly in sixes, lance-oblong, mucronate. Flowers usually in threes, on slender peduncles. Woodlands, especially N.

7. G. hispidulum Michx. Bedstraw. Perennial, from yellow roots; stems diffusely branched, smooth or slightly roughened, downy at the joints, erect or decumbent, 1–2 ft. long. Leaves 4 in a whorl, narrowly oval, acute, rough on the margins and mid-vein. Peduncles 1–3-flowered; flowers white; pedicels becoming reflexed. Fruit a bluish-black, roughened berry. On dry, sandy soil.*

II. MITCHELLA L.

A pretty, trailing, evergreen herb. Leaves roundish-ovate, petioled. Flowers fragrant, white or pinkish, dimorphous,

growing in pairs, joined by their ovaries. Calyx 4-toothed. Corolla funnel-shaped, with the lobes bearded within. Stamens 4, short. Style 1; stigmas 4, slender. Fruit double, composed of the united ovaries; really a drupe, containing 8 seed-like, bony nutlets, ripening into tasteless scarlet berries, which cling to the plant through the winter.

1. **M. repens** L. Partridge Berry, Squaw Vine, Two-Eye Berry. Common in dry woods, especially under evergreen coniferous trees.

III. BOUVARDIA Salisb.

Smooth perennials. Leaves lanceolate, thickish. Calyx 4-lobed, the divisions slender. Corolla with a long and narrow or rather trumpet-shaped tube, and spreading, 4-lobed limb. Anthers 4, inserted in the throat of the corolla, almost sessile. Stigmas 2, flat. Capsule globular, 2-celled, many-seeded. Flowers dimorphous.

1. **B. triphylla** Salisb. Three-Leaved Bouvardia. Somewhat shrubby. Leaves nearly smooth, ovate or oblong-ovate; the lower ones in threes, the upper ones sometimes in pairs. Corolla scarlet and slightly downy outside.

2. **B. leiantha** Benth. Downy-Leaved Bouvardia. Leaves rather downy. Corolla deep scarlet, smooth outside.

Both species cultivated from Mexico; in greenhouses.

IV. HOUSTONIA L.

Annual, biennial, or perennial herbs; stems erect or diffuse. Leaves entire; stipules often only a line connecting the bases of opposite leaves. Flowers small, solitary or clustered, dimorphous, the stamens projecting and the style short in one form, while in the other the stamens are short and the style projecting. Calyx 4-toothed, persistent. Corolla wheel-shaped to funnelform, 4-lobed. Stamens 4. Ovary 2-celled; style slender; stigmas 2. Fruit a 2-celled, few–many-seeded capsule, opening at the apex, free from the calyx.*

1. **H. cœrulea** L. Bluets, Innocence, Quaker Ladies, Eyebright. Perennial, from very slender rootstocks; stems tufted, erect, smooth, forking, 3–6 in. high. Leaves sessile, often hairy-fringed, the lower spatulate, the upper lanceolate. Flowers solitary,

on slender axillary peduncles. Calyx small. Corolla salverform, blue or white, yellow in the throat, smooth. Capsule laterally compressed, 2-lobed, shorter than the calyx. Common on open ground.*

2. H. patens Ell. Small Bluets. Annual; stem erect, branched at the base, forking above, smooth, 2–4 in. high. Lower leaves oval to ovate, petioled, the upper narrower and sessile.. Flowers solitary, on slender, axillary peduncles, blue or white. Calyx small. Lobes of the corolla about as long as the tube. Stamens and style projecting or included. Capsule compressed, as long as the calyx. Common on dry, open ground.*

3. H. purpurea L. Large Bluets. Perennial; stem stout, erect, simple or branched, smooth or downy, 4-angled, 6–12 in. high. Leaves ovate to ovate-lanceolate, sessile or short-petioled, 3–5-nerved, often hairy-fringed on the margins. Flowers in terminal cymes, purple to nearly white. Corolla funnelform, the tube longer than the limb, hairy within. Stamens and style projecting or included. Capsule compressed-globose, much shorter than the calyx. In dry, open woods.*

4. H. longifolia Gaertn. Long-Leaved Bluets. Perennial; stem erect, branched, smooth, 4-angled, 8–12 in. high. Leaves sessile, the lower oblanceolate or spatulate, the upper linear, 1-nerved. Corymbs terminal, few-flowered. Corolla light purple to white, the lobes much shorter than the tube. Capsule compressed-globose, nearly as long as the calyx. In dry, open woods.*

96. CAPRIFOLIACEÆ. Honeysuckle Family

Mostly shrubs. Leaves opposite, without true stipules. Flowers epigynous, often zygomorphic. Corolla tubular or wheel-shaped. Stamens usually as many as the corolla lobes and inserted on the corolla tube. Fruit a berry, drupe, or capsule.

I. DIERVILLA Mill.

Low, upright shrubs. Leaves taper-pointed, serrate. Flowers in loose terminal or axillary clusters or cymes. Calyx with a limb of 5 linear divisions. Corolla funnel-shaped, almost regularly 5-lobed. Stamens 5. Ovary slender, 2-celled, ripening into a 2-valved, many-seeded pod.

1. D. Lonicera Mill. Common Bush Honeysuckle. Bushy, 1–4 ft. high. Leaves ovate or oblong-ovate, petioled. Peduncles 1–3-flowered. Pods tapering to a slender point. Rocks, especially N.

2. D. japonica DC. WEIGELA. A stout, branching shrub, 3–6 ft. high. Leaves broadly oval, acute at the apex, rounded at the base, coarsely serrate, rough above, downy beneath, short-petioled. Flowers spreading, funnelform, rose color, 1–1½ in. long. Calyx lobes deciduous. Corolla downy without, the lobes spreading. Capsule oblong or spindle-shaped. Seeds with netted wings. Introduced from Japan; common in cultivation.*

II. LONICERA L.

Shrubs or woody vines. Leaves simple, usually entire, those of a pair often appearing as if joined together at the base, so that the stem seems to rise through them. Calyx tube ovoid, 5-toothed. Corolla tubular to bell-shaped, often knobbed at the base or 2-lipped. Stamens 5. Ovary 2–3-celled, ovules several in each cell; style slender; stigma knobbed. Fruit a 1–3-celled, 1–few-seeded berry.*

A

More or less upright bushes, not climbing.

1. L. tatarica L. TARTARIAN HONEYSUCKLE. A branching shrub, 5–8 ft. high. Leaves oval or ovate, heart-shaped, shining. Flowers many, showy, rose-colored. Fruit consisting of 2 red berries; somewhat united below at maturity. Cultivated from Asia.

2. L. canadensis Marsh. EARLY FLY HONEYSUCKLE. A straggling bush, 3–5 ft. high. Leaves ovate or oval, slightly heart-shaped, thin, at first downy beneath. Flowers straw-yellow, on short, slender peduncles. Corolla lobes nearly equal; tube pouched at the base. Fruit 2 separate red berries.

B

Stems twining.

3. L. japonica Thunb. JAPAN HONEYSUCKLE. Stem twining high; young branches downy. Leaves ovate to oblong, entire, smooth above, pale and downy beneath, all short-petioled. Peduncles axillary, 2-bracted, 2-flowered. Flowers white or pink, fading to yellow, 2-lipped, the lips nearly as long as the downy tube. Stamens and style projecting. Fruit black. Common in cultivation; introduced from Japan.*

4. L. sempervirens L. CORAL HONEYSUCKLE, TRUMPET HONEYSUCKLE. Stem twining high. Leaves evergreen (in the South), oval to oblong, obtuse, entire, smooth above, pale and often downy

beneath; the lower petioled, the upper pair nearly semi-orbicular and joined at the base. Flowering spikes terminal, bearing several whorls. Corolla about 2 in. long, slender, smooth; the limb short, nearly equally 5-lobed, scarlet without, bright yellow within. Stamens slightly projecting; fruit red. On low ground; often cultivated.*

5. L. Caprifolium L. EUROPEAN HONEYSUCKLE. A moderately high-climbing shrub. Leaves smooth and deciduous, several of the upper pairs united at their bases to form a flattish disk or somewhat cup-shaped leaf. Flowers in a single terminal whorl, very sweet-scented. Corolla whitish, red, or yellow, 2-lipped, with the lips recurved. Cultivated from Europe.

6. L. Sullivantii Gray. YELLOW HONEYSUCKLE. Stem somewhat twining. Leaves oval to obovate, obtuse, entire, green above, with a bloom beneath, the lower short-petioled, the upper sessile or joined at the base. Flowers in crowded, terminal whorls, bright yellow, fragrant. Corolla tube slender, 1–1½ in. long, bilabiate, 4-lobed, pubescent within. Stamens and style projecting. On river banks and hillsides; often cultivated.*

III. SYMPHORICARPOS Ludwig

Shrubs. Leaves short-petioled, deciduous. Flowers in axillary clusters. Calyx tube globose, 4–5-toothed. Corolla bell-shaped, 4–5-lobed, sometimes knobbed at the base, smooth or hairy within. Stamens 4–5. Ovary 4-celled; 2 of the cells with a single fertile ovule in each, the other cells with several abortive ovules; style slender; stigma knobbed or 2-lobed. Fruit a 4-celled, 2-seeded berry.*

1. S. racemosus Michx., var. **lævigatus.** SNOWBERRY. An ornamental shrub, 2–3 ft. high. Flowers in loose terminal racemes, which are often leafy. Corolla bell-shaped, much bearded inside, pinkish-white. Stamens and style not projecting. Berries rather large, snow-white, remaining long on the branches. Rocky banks, often cultivated.

IV. LINNÆA L.

A very small, slender, creeping evergreen shrub; branches inclined, ending in a slender, erect, 2-flowered peduncle. Leaves opposite, without stipules. Flowers nodding, on slender pedicels, with 2 bractlets. Calyx tube ovoid; limb 5-lobed. Corolla nearly bell-shaped, 5-lobed. Stamens 4, inserted near the base of the corolla; 2 of them longer than the other 2.

Ovary 3-celled; style thread-like; stigma knobbed; ovules many in 1 cell, solitary in the 2 others. Fruit nearly globose, 1-seeded.

1. **L. borealis** L. TWIN FLOWER. A beautiful, delicate plant. Corolla pale pink, very fragrant. Moist woods, in moss and cold bogs N.

V. TRIOSTEUM L.

Coarse, hairy, perennial herbs. Leaves large, those of each pair somewhat joined at the base, so that the stem appears to rise through them. Calyx tube ovoid; divisions of the limb leaf-like, lance-linear, persistent. Corolla knobbed at the base, nearly equally 5-lobed. Ovary usually 3-celled, ripening into a drupe with 3 nutlets.

1. **T. perfoliatum** L. TINKER WEED, WILD COFFEE, FEVERWORT, HORSE GENTIAN. Stem unbranched, soft-hairy, 2–4 ft. high. Leaves spatulate-ovate, abruptly narrowed at the base, 4–7 in. long and 2–4 in. wide, bordered with a fringe of hairs. Flowers dark brownish-purple. Corolla about ½ in. long, sticky-downy. Fruit ellipsoidal, orange-colored when ripe. Common along fence rows and in rocky woods.

VI. VIBURNUM L.

Shrubs or small trees. Leaves simple, entire, dentate or lobed, with or without stipules. Flowers small, white, in terminal cymes; the outer flowers of the cyme sometimes greatly enlarged and sterile. Calyx tube very small, 5-toothed. Corolla wheel-shaped or bell-shaped, 5-lobed. Stamens 5, inserted in the tube of the corolla. Ovary 1–3-celled, 1–3-ovuled, but only 1 ovule maturing; style short, 3-lobed. Fruit a 1-seeded drupe, with soft pulp.*

A

Flowers around the margin of the cyme without stamens or pistils, large and showy.

1. **V. alnifolium** Marsh. HOBBLEBUSH, WITCH HOBBLE. A shrub about 5 ft. high, with the branches reclining and often rooting and forming loops (whence the popular names). Leaves very large, roundish, abruptly taper-pointed, serrate, with a rusty down on the petioles and veinlets. Cymes very broad and showy. Fruit red, not eatable.

2. V. Opulus L., var. **americanum.** Cranberry Tree, High-Bush Cranberry. A handsome, upright shrub. Leaves 3–5-ribbed and 3-lobed. Fruit bright red, juicy, very acid, and used as a substitute for cranberries. Common N. The form known as "snowball," with all the flowers showy and sterile, is cultivated from Europe.

B

Flowers all small and bisexual.

3. V. acerifolium L. Maple-Leaved Arrowwood. A slender shrub, 3–6 ft. high. Leaves broadly ovate to heart-shaped, palmately veined and 3-lobed, serrate or nearly entire, petioled, downy, becoming smooth above. Cymes peduncled, about 7-rayed, 2–3 in. wide; sterile flowers none. Fruit oval, black; stone flat, 2-ridged on the edges. In dry, open woods.*

4. V. dentatum L. Arrowwood. A shrub 8–15 ft. high. Leaves broadly ovate to oval, acute at the apex, rounded or heart-shaped at the base, coarsely dentate, smooth above, hairy in the axils of the veins beneath, short-petioled. Cymes long-peduncled, 7-rayed, 2–3 in. wide; sterile flowers none. Calyx smooth. Fruit globose, dark blue; stone compressed, grooved on one side. In rich, damp soil.*

5. V. nudum L. Withe-Rod. A shrub 8–12 ft. high. Leaves ovate to lanceolate, entire or slightly toothed, acute at both ends, thick, smooth above, the veins prominent beneath; petiole short. Cymes short-peduncled, 5-rayed; sterile flowers none. Fruit ovoid, blue. Common in swamps.*

6. V. Lentago L. Nannyberry, Sheepberry. A shrub or small tree, sometimes 30 ft. high. Leaves ovate, sharply serrate, taper-pointed, usually smooth on both sides. Flower clusters large compound cymes. Fruit oval, ½ in. or more long, bluish-black, with a bloom, eatable. In woods and on banks of streams.

7. V. prunifolium L. Black Haw. A small tree, 15–20 ft. high. Leaves oval to ovate, acute or obtuse at each end, finely and sharply serrate, smooth and shining above, often slightly downy beneath; petioles dilated and rusty-downy. Cymes sessile, large, 4–5-rayed; sterile flowers none. Fruit oval, bluish-black, eatable. In rich, moist woods.*

VII. SAMBUCUS L.

Shrubs with odd-pinnate leaves. Calyx limb minute or wanting. Flowers very many, small, white, in compound cymes. Corolla with a small, somewhat urn-shaped tube, and a flattish, spreading, 5-cleft limb. Stamens 5. Stigmas 3, sessile. Fruit a globular, pulpy drupe, 3-seeded, appearing like a berry.

1. S. canadensis L. Common Elder. Stems 5–10 ft. high, with a thin cylinder of wood surrounding abundant white pith. Leaflets 5–11, oblong, taper-pointed, smooth. Cymes flat and often very large. Fruit purplish-black, insipid or almost nauseous, but somewhat used in cookery.

2. S. racemosa L. Red-Berried Elder. More woody, with brown pith. Leaflets fewer, downy beneath, especially when young. Cymes panicled and somewhat pyramidal. Fruit scarlet.

97. VALERIANACEÆ. Valerian Family

Herbs, rarely shrubs. Leaves opposite, without stipules. Flowers epigynous, small, usually not actinomorphic, in forking cymes. Corolla funnel-shaped, the base often with a sac or spur. Stamens 1–3 or 5, inserted at the base of the corolla tube; filaments slender, anthers versatile. Ovary cells 3; two of them not ovule-bearing, the third with a single ovule hanging from the top; style thread-like; stigma blunt or 2–3-lobed. Fruit small, not splitting open.

I. VALERIANA L.

Perennial, rarely annual, herbs. Basal leaves crowded; stem leaves opposite or whorled, entire or pinnately cut. Flowers in corymbed, headed, or panicled cymes. Limb of the calyx consisting of several plumy bristles. Lobes of the corolla 5 or rarely 3–4, unequal. Stamens 3. Stigma knobbed. Fruit flattened, ribbed, 1-celled, 1-seeded.

1. V. edulis Nutt. An upright, straight-stemmed plant, 1–4 ft. high. Leaves all thickish and closely fringed with short hairs; root leaves linear-spatulate or lanceolate-spatulate, entire; stem leaves pinnately parted, the 3–7 divisions long and narrow. Flowers almost diœcious in a long, interrupted panicle. Corolla whitish. Root long and stout, eaten by Indians. Low ground and wet prairies, especially N.W.

2. V. officinalis L. Garden Valerian. Plant smooth or hairy below, strong smelling. Rootstock short. Leaves all pinnate; basal leaves long-petioled, soon withering; stem leaves 2–5 in. long, sessile, the leaflets lanceolate, entire or serrate. Corolla pale pink. Rootstocks strong-scented, used in medicine. Cultivated from Europe.

II. VALERIANELLA Hill

Annual herbs; stem forking regularly. Leaves opposite, entire or dentate. Flowers in crowded, terminal, bracted cymes. Calyx limb toothed or wanting. Corolla white or purplish, funnelform, 5-lobed. Stamens 3. Style 3-lobed. Fruit 3-celled, 1-seeded.*

1. V. Locusta Betcke. Lamb Lettuce. Stem erect, smooth, or downy at the nodes, many times forked, 9–12 in. high. Basal leaves tufted, spatulate to obovate, entire; the upper lanceolate, dentate, sessile. Cymes short-peduncled, bracts linear. Flowers pale blue. Fruit compressed, oblique. On rich soil in waste places. Sometimes cultivated for salad. Introduced from Europe.*

2. V. radiata Dufr. Corn Salad. Stem erect, smooth above, downy below, 2–4 times forked, 8–12 in. high. Lower leaves spatulate, entire; the upper lanceolate, clasping at the base, dentate. Cymes compact; bracts lanceolate. Flowers white. Fruit ovoid, downy, furrowed. On damp soil.*

98. CUCURBITACEÆ. Gourd Family

Somewhat succulent, tendril-bearing, prostrate or climbing, herbaceous plants. Leaves alternate, with stipules. Flowers epigynous, dicœcious or moncœcious, often sympetalous. Calyx limb (if present) 5-lobed. Corolla usually 5-lobed and with its tube more or less united with the calyx tube. Stamens perigynous or borne upon the corolla; the anthers usually joined in long, serpentine ridges. Ovary 3-celled; stigmas 2 or 3. Fruit generally a pepo (like the melon, squash, and pumpkin), but sometimes dry. Seeds commonly large and flat. A large family, mostly of tropical plants, many with eatable fruit, but some species poisonous.

I. CUCURBITA L.

Annual or perennial herbs; stem trailing or climbing, 2–20 ft. long. Leaves angular-lobed; tendrils branching. Flowers moncœcious, solitary or in small clusters. Calyx 5-toothed, the limb deciduous. Corolla bell-shaped, 5-lobed. Staminate flowers with 3 stamens and no pistil; pistillate flowers with 1 pistil and 3 imperfect stamens. Style short; stigmas 3–5, each 2-lobed. Fruit 1-celled, with numerous seeds on the 3 parietal placentæ.*

1. C. fœtidissima HBK. Missouri Gourd. Stem stout, rough and hairy. Root very large, carrot-shaped. Leaves thick, triangular heart-shaped. Flowers 3–4 in. long. Fruit globose or somewhat obovoid, 2–3 in. in diameter. Dry soil W. and S.W.

2. C. Melopepo L. Summer Squash. Stem rough-hairy, angled, 2–5 ft. long. Leaves broadly heart-shaped, angularly 3–5-lobed, rough. Flowers yellow, short-peduncled. Fruit roundish, longitudinally compressed, the margin smooth, wavy, or tubercular. Common in cultivation.*

3. C. verrucosa L. Crookneck Squash. Stem rough-hairy, angled and striate, 5–10 ft. long. Leaves cordate, deeply 5-lobed, very rough, long-petioled. Flowers light yellow, long-peduncled. Fruit clavate, the base often slender and curved, smooth or tuberculate, very variable. Common in cultivation.*

II. CUCUMIS L.

Annual herbs; stems trailing, usually shorter and more slender than in the preceding genus; tendrils not forked. Leaves varying from entire or nearly so to deeply cut. Sterile flowers in clusters, fertile ones solitary in the leaf axils. Corolla of 5 acute petals, which are but little joined at the base. Stamens not evidently united. Style short; stigmas 3, each 2-lobed. Fruit rather long. Seeds not large, lance-oblong, not margined.

1. C. sativus L. Cucumber. Leaves somewhat lobed, the middle lobe largest. Fruit more or less covered when young with rather brittle, blackish prickles, which fall off as it ripens. Cultivated from S. Asia. [Other varieties of the genus *Cucumis* are the muskmelon, cantaloupe, and nutmeg melon. Other commonly cultivated genera are *Citrullus*, the watermelon, and *Lagenaria*, the bottle gourd. Two wild genera, *Echinocystis*, the wild cucumber, and *Sicyos*, the star cucumber, which blossom through the summer and autumn, are common in the northern states and the Middle West.]

99. CAMPANULACEÆ. Campanula Family

Herbs, with milky juice. Leaves alternate, without stipules. Flowers epigynous, actinomorphic, not clustered. Calyx 5-lobed. Corolla regular, bell-shaped, 5-lobed. Stamens 5, usually free from the corolla and not united. Style 1, usually hairy above; stigmas 2 or more. Fruit a capsule, 2 or more celled, many-seeded.

I. SPECULARIA Fabricius

Annual; stems slender, angled. Leaves entire or toothed. Flowers axillary, regular, solitary or in small clusters, sessile, bracted. Calyx tube slender, 3–5-parted. Corolla wheel-shaped, 5-lobed. Stamens with the filaments flattened and shorter than the anthers. Ovary 3-celled, many-ovuled; stigmas 3. Fruit a prismatic, 3-celled, many-seeded capsule.*

1. S. perfoliata A. DC. SPECULARIA. Stem erect, simple or branched from the base, angles roughened, 10–20 in. high. Leaves ovate to lanceolate, acute at the apex, sessile, crenate or entire, the upper bract-like. Flowers solitary or in pairs. Corolla blue, often wanting. Capsule cylindrical, smaller above. In waste places.*

II. CAMPANULA L.

Annual, biennial, or perennial herbs. Flowers solitary, racemed or spiked, regular, blue or white. Calyx 5-lobed or parted. Corolla wheel-shaped to bell-shaped, 5-lobed. Stamens 5, free from the corolla, distinct; filaments dilated at the base. Ovary 3–5-celled, many-ovuled; style 3-parted. Capsule short, bearing the persistent calyx lobes at its apex, many-seeded, splitting open on the sides.*

1. C. americana L. TALL BELLFLOWER. Annual or biennial. Stem erect, usually unbranched, 3–6 ft. high. Leaves varying from ovate to lanceolate, serrate, 2½–6 in. long. Spike 1–2 ft. long. Corolla wheel-shaped, light blue, about 1 in. in diameter. Moist, rich soil, especially in thickets.

2. C. rotundifolia L. HAREBELL. A slender, smooth, branching perennial, 5–12 in. high. Root leaves broadly ovate-heart-shaped, generally somewhat crenate, soon withering; stem leaves varying from linear to narrowly lanceolate, entire. Pedicels slender; flowers solitary or somewhat racemed, the buds erect but the fully opened flower drooping. Calyx teeth erect, awl-shaped. Corolla bell-shaped, ½–1 in. long, its lobes short and recurved. Rocky hillsides, especially N.

3. C. aparinoides Pursh. MARSH BELLFLOWER. Stem angular, unbranched, slender, weak, and leaning on the grass among which it usually grows, the angles clothed with minute, backward-pointing prickles. Leaves lance-linear, nearly entire. Flowers terminal, about ⅓ in. long, white. Corolla bell-shaped. Wet meadows, in tall grass.

100. COMPOSITÆ. Composite Family

Flowers epigynous, in a dense head, on a common receptacle, surrounded by an involucre composed of many bracts (Fig. 29), with usually 5 stamens inserted on the corolla, the anthers united into a tube which surrounds the style.

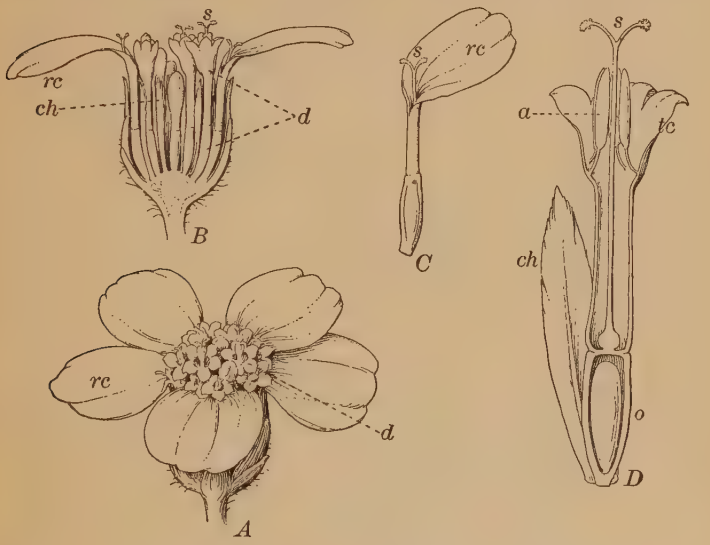


Fig. 29. Flower cluster and flowers of yarrow

A, flower cluster; *B*, section of flower cluster; *C*, a ray flower; *D*, a disk flower. *a*, anthers; *ch*, chaff of disk; *d*, disk flowers; *o*, ovary; *rc*, corollas of ray flowers; *s*, stigmas; *tc*, corolla of tubular flower. (*A*, *B*, *C*, 7 times natural size; *D*, 18 times natural size)

Calyx with its limb sometimes wanting; when present taking the form of scales, bristles, etc., known as *pappus* (Fig. 30). Corolla either strap-shaped (Fig. 29, *rc*) or tubular (Fig. 29, *tc*); in the former case often 5-toothed, in the latter usually 5-lobed. Style 2-cleft above. Fruit an akene, often provided with means of transportation. This is the largest family of flowering plants and among the most specialized for insect

pollination. The genera of the northern United States are divided into two suborders: I. TUBULIFLORÆ, corolla of the bisexual flowers tubular and 5-lobed; II. LIGULIFLORÆ, corollas all strap-shaped and flowers all bisexual.

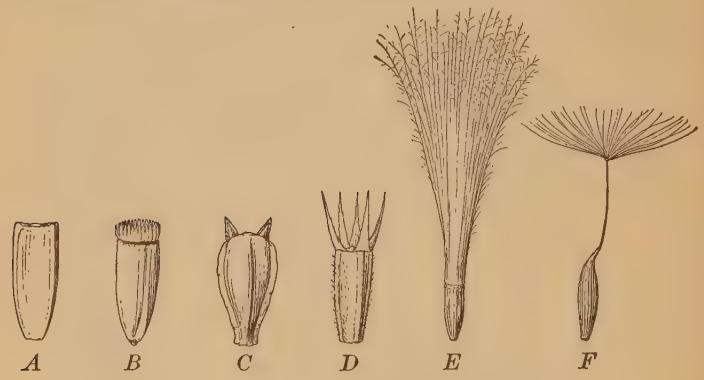


FIG. 30. Akenes with various types of pappus

A, *Rudbeckia*, pappus wanting; *B*, *Cichorium*, pappus a crown of fine scales; *C*, *Coreopsis*, pappus of 2 small scales; *D*, *Helenium*, pappus a crown of conspicuous scales; *E*, *Cirsium*, pappus a tuft of plumose hairs; *F*, *Lactuca*, pappus borne on a long beak

I. TUBULIFLORÆ [1]

Corollas some or all of them tubular.

Rays white, pink, or purplish.

Rays many; akenes flat; pappus wanting; low herbs. Bellis, I

Rays many; akenes cylindrical or winged, grooved; pappus wanting; tall herbs or shrubby. Chrysanthemum, X

Rays many; akenes flat; pappus of an outer row of minute scales and an inner row of delicate bristles. Erigeron, II

Rays many; akenes cylindrical or ribbed; pappus wanting; strong-scented, branching herbs. Anthemis, IX

Rays few. Achillea, VIII

[1] The characters in this key are not necessarily true of all species in the genera referred to, but only of those described below.

Rays yellow.
Disk purplish-brown. Rudbeckia, IV
Disk gray. Lepachys, V
Disk yellow.
Involucre of 2 rows of bracts, the outer rather leaf-like. Coreopsis, VI
Involucre of reflexed scales; pappus of 5–8 scales. Helenium, VII
Involucre of erect scales; pappus of abundant soft hairs. Senecio, XI
Rays none, but the marginal flowers sterile and their tubular corollas partly flattened like rays. Centaurea, XIII
Rays none, and marginal flowers like the others; scales of the involucre not prickly. Antennaria, III
Rays none and marginal flowers like the others; scales of the involucre overlapping in many rows, prickly-pointed. Cirsium, XII

II. LIGULIFLORÆ

Corollas all strap-shaped.

Corollas blue (rarely pinkish); akenes not beaked. Cichorium, XIV
Corollas blue; akenes beaked. Lactuca, XIX
Corollas yellow.
(*a*) Akenes truncate; pappus double, of chaff and bristles. Krigia, XV
(*b*) Akenes columnar; pappus of tawny, rough bristles; stem scape-like. Hieracium, XXII
(*c*) Akenes spindle-shaped, not beaked; pappus of plumed bristles. Leontodon, XVI

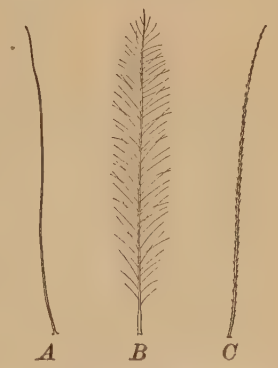


FIG. 31. Types of pappus hairs

A, smooth hair of dandelion; *B*, plumose hair of fall dandelion; *C*, rough or barbed hair of hawkweed. (7 times natural size)

(*d*) Akenes ovoid to spindle-shaped, long-beaked, 4–5-ribbed; pappus white, soft, and abundant. Taraxacum, XVII

(*e*) Akenes nearly as in XVII; pappus tawny. Pyrrhopappus, XXI

(*f*) Akenes not flattened, with or without beak, 10-ribbed; pappus of abundant stiff, hair-like white bristles. Agoseris, XX

(*g*) Akenes flattened, beaked; pappus soft, white, the hairs soon falling off; leafy-stemmed herbs. Lactuca, XIX

(*h*) Akenes flattened, not beaked; pappus abundant, soft, white; leafy-stemmed, spiny-leaved herbs. Sonchus, XVIII

I. TUBULIFLORÆ

I. BELLIS L.

Small herbs. Leaves usually all basal, petioled. Heads solitary, disk yellow, ray flowers white or pink; involucre bell-shaped; bracts in 1 or 2 rows, green; receptacle conical. Ray flowers many, in a single row, pistillate; disk flowers tubular, bisexual, 4–5-toothed; forks of the style short, thick, tipped by roughened cones. Fruit flattened, obovate; pappus wanting.

1. **B. integrifolia** Michx. American Daisy. A branching annual or biennial herb, 4–12 in. high. Upper leaves lanceolate or oblong, the lower ones obovate-spatulate. Heads borne on slender peduncles; rays violet-purple. Prairies, especially S.W.

2. **B. perennis** L. English Daisy, Scotch Daisy. An apparently stemless perennial. Leaves obovate-spatulate, smooth or hairy. Heads ¾–1 in. in diameter, very pretty, the rays delicate. Cultivated from Europe.

II. ERIGERON L.

Herbs. Leaves usually sessile. Heads many-flowered, flat or nearly hemispherical, the rays numerous, narrow, pistillate. Scales of the involucre narrow and overlapping but little. Akenes flattish, crowned with a single row of hair-like bristles, or sometimes with shorter bristles or scales outside these. Disk yellow, rays white, pinkish, or purple.

B. Fl. species 5 (*Leptilon*).

1. E. pulchellus Michx. Robin's Plantain. Perennial; soft-hairy; stems sometimes throwing out offsets from the base; simple, erect, 1–2 ft. high. Basal leaves obovate-obtuse, somewhat serrate; stem leaves few, lance-oblong, acute, clasping. Heads rather large, 1–9, on long peduncles, with 50–60 long, rather broad, bluish-purple or reddish-purple rays. Thickets and moist banks.

2. E. philadelphicus L. Perennial; rather hairy; stems slender, about 2 ft. high. Basal leaves spatulate and toothed; stem leaves usually entire and strongly clasping, sometimes with a heart-shaped or eared base. Heads several, small, long-petioled; rays exceedingly numerous, thread-like, reddish-purple or flesh color. In damp soil.

3. E. annuus Pers. Common Fleabane. Annual or biennial. Stem grooved and stout, branching, 2–5 ft. high, with scattered hairs. Lowest leaves petioled, ovate, coarsely toothed; those higher up the stem successively narrower, sessile. Heads in a large, loose corymb; rays short, white or purplish. Fields and waste ground.

4. E. ramosus BSP. Daisy Fleabane. Annual or biennial. Considerably resembling the preceding species, but with entire leaves, smaller and less branched stem, smaller heads, and longer rays. Fields and pastures.

5. E. canadensis L. Horseweed, Butterweed, Colt's Tail. Annual; stem erect, 1–5 ft. high. Leaves linear, those of the stem entire. Heads very numerous and small, panicled; the white rays hardly longer than the pappus. A common and troublesome weed.

III. ANTENNARIA Gaertn.

Perennial woolly herbs. Leaves partly basal, the stem leaves alternate. Heads small, many-flowered, dicœcious; the flowers all tubular. Involucre of thin, dry, white or colored bracts, imbricated in several series. Receptacle convex or flat, without chaff. Pistillate flowers with very slender tubular corollas and abundant pappus of hair-like, naked bristles, somewhat united at the base; pappus of the sterile flowers thickened and club-shaped at the tips. Akenes small, cylindrical or flattish.

1. A. Parlinii Fernald. Stolons ascending, leafy throughout; stems rather stout, at length 12–20 in. high, they and the stem leaves more or less downy with purplish glandular hairs. Basal leaves and those at the tips of the stolons at length smooth and bright green above; lower stem leaves abundant, oblong or narrower, obtuse or nearly so. Heads corymbed. Style at length crimson. Rich soil, frequently in open woods.

2. A. plantaginifolia Richards. Common Everlasting, Pussy's Toes. Stolons ascending, leafy throughout; stems slender, 4–20 in. high. Basal leaves and those at the tips of the stolons pale and very downy or covered with cobweb-like hairs above; stem leaves scattered, lanceolate, taper-pointed. Heads more or less closely corymbed. Styles crimson. In dry soil, very common.

3. A. solitaria Rydb. Stolons when well developed procumbent, leafy only at the tip; stems 2–8 in. high. Basal leaves obovate-spatulate, densely downy beneath, covered with cobweb-like hairs above, but becoming smoothish; stem leaves few, small, lying close to the stem. Heads solitary. Styles crimson. Rich wooded hillsides, central and south central states.

IV. RUDBECKIA L.

Perennial or biennial. Leaves alternate, entire or lobed. Heads radiate, long-peduncled, many-flowered; bracts imbricated in 2–3 series, spreading; receptacle convex or long-conical, with concave, chaffy scales. Ray flowers yellow, neutral; disk flowers purple to brown, bisexual. Akenes smooth, 4-angled, truncate. Pappus a few short teeth or wanting.*

1. R. hirta L. Cone Flower, Black-Eyed Susan. Annual or biennial; stem erect, rough-hairy, simple or branched, 2–3 ft. high. Leaves lanceolate to oblong, thick, obscurely serrate, rough-hairy, 3-ribbed; the lower petioled, the upper sessile. Heads few, long-peduncled; bracts rough-hairy, spreading. Ray flowers 10–20, orange-yellow; disk flowers purplish-brown. Chaff acute, hairy at the apex. Pappus none. On dry, open ground.

V. LEPACHYS Raf. (RATIBIDA)

Perennial herbs. Leaves alternate, pinnately divided. Heads radiate, long-peduncled, many-flowered; bracts few, small, spreading. Receptacle columnar or slender, the chaff of concave truncate scales. Ray flowers yellow or with brown at the base, neutral; disk usually grayish.

1. L. pinnata T. & G. Gray Cone Flower. Stem slender, branching, often 4 ft. or more high, gray with minute close-lying hairs. Leaves mostly large, pinnately 3–7-divided; the basal ones with long petioles, stem leaves sessile, the uppermost small. Disk oblong, gray or at length brown. Rays 4–10, light yellow, drooping, often 2 in. long. In dry prairie soil and borders of thickets.

2. L. columnaris T. & G. PRAIRIE CONE FLOWER. Stem rough-hairy, slender, usually branching from the base, 1–2 ft. high. Leaves pinnately divided into oblong to narrowly linear segments. Disk columnar, sometimes more than 1 in. long. Rays 4–10, drooping, yellow or partly or entirely brownish-purple, as long as or somewhat shorter than the disk. On dry prairies, especially W. and S.W.

VI. COREOPSIS L.

Annual or perennial herbs. Leaves opposite or the upper alternate, entire or pinnately divided. Heads radiate, solitary or corymbed, many-flowered; bracts in 2 rows of about 8 each, the inner membranaceous and appressed, the outer narrower and spreading; receptacle chaffy. Ray flowers neutral; disk flowers tubular, bisexual. Akenes compressed, oval to oblong, often winged. Pappus of 2 scales or bristles, or wanting.*

1. C. tinctoria Nutt. GARDEN COREOPSIS. Annual; stem erect, smooth, branched, 2–3 ft. high. Leaves 2–3 times pinnately divided, the divisions linear; lower leaves petioled, the upper often sessile and entire. Heads 1–1½ in. wide, on slender peduncles; inner bracts brown with scarious margins, outer bracts very short. Ray flowers about 8, yellow with a brown base, 3-lobed at the apex. Akenes linear. Pappus minute or none. Common in gardens.*

2. C. lanceolata L. TICKSEED. Perennial; stem slender, erect or ascending, smooth or slightly downy below, simple, 9–15 in. high. Leaves opposite, the lower spatulate to elliptical, sometimes lobed, on long, hairy-fringed petioles; the upper lanceolate, sessile. Heads few, on long peduncles; bracts ovate-lanceolate, the outer narrower. Ray flowers 6–10; rays 3–5-lobed, bright yellow. Akenes oval, broadly winged, warty. Pappus of 2 teeth. On rich, dry soil, S. and E.*

3. C. grandiflora Hogg. LARGE-FLOWERED TICKSEED. Usually perennial; stem smooth, commonly branched above, 1–3 ft. high. Most of the leaves once or twice pinnately parted, the lower sometimes entire, on slender petioles; segments of most of the stem leaves linear or thread-like. Heads usually several, 1¼–2 in. in diameter, on long peduncles; outer bracts lanceolate, narrower and shorter than the inner ones. Rays 6–10, yellow. Akenes oblong, with broad wings when ripe. In moist soil, especially S.W.

4. C. auriculata L. RUNNING TICKSEED. Perennial; stem ascending or decumbent, weak, smooth, nearly simple, 6–15 in. long. Leaves ovate to oval, entire or with 2–4 small and rounded lobes at the base, downy, long petioled. Heads 1–1½ in. wide, few or single; outer bracts narrower than the inner. Rays 6–10, mostly 4-toothed

at the apex; chaff as long as the flowers. Akenes oblong, the wings narrow and thickened; pappus of 2 minute teeth. In rich woods.*

5. C. palmata Nutt. STIFF TICKSEED. Perennial; stem stiff, smooth, little or not at all branched, very leafy, 1–3 ft. high. Leaves 3-cleft, broadly wedge-shaped, stiff; the lobes linear-oblong, middle one often 3-lobed. Heads on short peduncles, few or solitary, $1\frac{1}{4}$–2 in. in diameter; bracts of the outer series narrower than the inner ones, slightly shorter. Rays 6–10, bright yellow, broad, usually 3-toothed. Akenes oblong, with narrow wings. Dry prairies and thickets W.

6. C. verticillata L. Perennial; stem smooth, stiff, slender, branching freely, leafy, 1–2 ft. high. Leaves divided into 3 sessile leaflets, the latter once or twice pinnately parted into narrowly linear or thread-like divisions. Heads $1\frac{1}{4}$–$1\frac{1}{2}$ in. in diameter; outer bracts much narrower than the inner ones. Rays 6–10, yellow. Akenes oblong, with narrow wings. In dry or moist soil, sometimes cultivated.

VII. HELENIUM L.

Annual or perennial. Leaves alternate, forming wings on the stem. Heads radiate, peduncled, many-flowered; bracts in 2 series, the outer linear and spreading, the inner few and scale-like; receptacle naked, convex or oblong. Ray flowers pistillate and fertile, or neutral, the rays wedge-shaped, 3–5-lobed; disk flowers bisexual, tubular, 4–5-lobed. Akenes top-shaped, hairy, ribbed; pappus of 4–5 entire, toothed or awned scales.*

1. H. nudiflorum Nutt. SNEEZEWEED. Perennial; stem slender, erect, downy, branched above, 1–2 ft. high. Leaves lanceolate, entire or slightly toothed, the lower petioled, the upper sessile. Heads numerous. Ray flowers 10–15, neutral, yellow or yellow and brown; disk flowers purple. Akenes hairy on the ribs; pappus of ovate, minutely toothed, awned scales. Common on river banks S.*

VIII. ACHILLEA L.

Perennial. Leaves alternate, pinnately divided. Heads with ray flowers in a terminal corymb; involucral bracts imbricated in several series, the outer shorter; receptacle chaffy. Ray flowers white or pink, pistillate and fertile; disk flowers bisexual, tubular, 5-lobed. Akenes oblong, compressed, slightly margined; pappus none.*

1. A. Millefolium L. YARROW. Stems often clustered, erect from a creeping rootstock, simple, downy or woolly, 1–2 ft. high. Leaves

lanceolate or oblong, the segments finely cut and divided, smooth or downy, the lower petioled, the upper sessile. Heads small, numerous, in flat-topped corymbs; bracts downy. Ray flowers 4–5, white or pink, rays 3-lobed at the apex. Common in old fields.*

IX. ANTHEMIS L.

Aromatic or ill-scented herbs. Leaves finely pinnately divided. Heads many-flowered, with ray flowers. Rays pistillate or neutral. Involucre of many small, dry, close-pressed scales. Akenes nearly cylindrical, generally ribbed, barely crowned or naked at the summit.

1. A. Cotula L. Mayweed, Dog Fennel. Leaves irregularly cut into very many narrow segments. Heads small, produced all summer. Disk yellow. Rays rather short, white, neutral. A low, offensive-smelling annual weed, by roadsides and in barnyards.

2. A. arvensis L. Field Chamomile. Annual or biennial. Resembling *A. Cotula*, but without offensive smell. Leaves less finely once or twice pinnately parted. In fields and waste ground. Naturalized from Europe.

X. CHRYSANTHEMUM L.

Perennials, with toothed, pinnately cut or divided leaves. Heads nearly as in *Anthemis*, except that the ray flowers are pistillate.

1. C. Leucanthemum L. Oxeye Daisy, Whiteweed, Bull's-Eye, Sheriff Pink. Stem erect, unbranched or nearly so, 1–2 ft. high. Basal leaves oblong-spatulate, petioled, deeply and irregularly toothed; stem leaves sessile and clasping, toothed and cut, the uppermost ones shading off into bracts. Heads terminal and solitary, large and showy, with a yellow disk and many white rays. A troublesome but handsome perennial weed.* Naturalized from Europe, chiefly E.

2. C. frutescens L. Marguerite. Erect, branching, perennial, woody below, smooth, and with a pale bloom. Divisions of the leaves linear, with the uppermost leaves often merely 3-cleft bracts. Heads long-peduncled, showy, with a yellow disk and large, spreading white rays. Cultivated in greenhouses. From the Canary Islands.

XI. SENECIO L.

Annual or perennial; stems often hollow. Leaves alternate, entire or pinnately divided. Heads with or without rays, in terminal corymbs; bracts mostly in a single row, often with a

few shorter ones at the base; receptacle naked or pitted. Ray flowers yellow or orange, pistillate and fertile when present; disk flowers tubular, bisexual. Akenes cylindrical or compressed, not beaked or winged, 5–10-ribbed, downy; pappus of numerous slender white hairs.*

1. S. glabellus Poir. BUTTERWEED. Annual; stem erect, ridged, hollow, often woolly when young and becoming smooth with age, branched above, 1–3 ft. high. Leaves lyrate-pinnatifid, thin, the lower petioled, the upper sessile. Heads radiate in a terminal corymb; bracts linear, acute. Ray flowers about 12, yellow. Akenes slightly rough-hairy on the angles; pappus rough, longer than the involucre. Common on low ground.*

2. S. aureus L. GOLDEN RAGWEED. Perennial; stems often tufted, erect, slender, woolly when young, branched above, 18–30 in. high. Lower leaves broadly ovate, obtuse at the apex, heart-shaped at the base, crenate, long-petioled; stem leaves lanceolate and often pinnatifid, the upper small and sessile. Heads radiate, corymbed, on slender peduncles. Ray flowers 8–12, bright yellow. Akenes smooth. In wet soil; very variable.*

3. S. tomentosus Michx. WOOLLY RAGWEED. Perennial; woolly throughout; stem stout, erect, mostly simple, 2–3 ft. high. Lower leaves ovate to oblong, crenate or entire, obtuse, long-petioled; stem leaves few, elliptical to oblanceolate, serrate or toothed, acute, sessile. Heads radiate, $\frac{3}{4}$ in. wide, on slender peduncles; bracts narrow, becoming smooth. Ray flowers 12–15, yellow. Akenes hairy. In damp soil.*

XII. CIRSIUM Hill. (CARDUUS)

Biennial or perennial; stem erect, simple or branched. Leaves alternate, prickly, often forming wings on the stem. Heads discoid, terminal and solitary or corymbed, many-flowered; bracts overlapping in many series, the outer shorter, usually spine-pointed; receptacle bristly. Corollas purplish or nearly white, the tube slender, deeply 5-cleft. Akenes oblong, 4-angled, smooth or ribbed; pappus of numerous simple or plumose bristles. [Most of our commoner species blossom in the late summer and autumn.]*

1. C. spinosissimum Scop. YELLOW THISTLE. Biennial or perennial; stem erect, stout, woolly when young, becoming smooth, often purple, branched, 1–3 ft. high. Leaves pinnately cut, with very spiny teeth, mostly sessile and clasping, smooth and green on both sides. Heads

large, surrounded by a whorl of linear-oblong, comb-like leaves; involucral bracts linear, ciliate, not spine-tipped. Flowers purple or yellowish. On sandy soil E. and S.*

2. C. virginianum Michx. Early Wood Thistle. Stem woolly, slender, little or not at all branched, 1–3 ft. high. Leaves lanceolate, green above, covered beneath with dense white wool, the margins beset with prickly bristles, entire or sinuate-lobed, the lower ones sometimes pinnately cut into triangular-lanceolate lobes. Heads small, purple, on long leafless peduncles; outer scales of the involucre merely bristle-pointed. In dry woods and thickets.

XIII. CENTAUREA L.

Herbs. Leaves entire or cut, often spiny-toothed. Heads single; involucre ovoid or globose; bracts closely overlapping, often fringed, dry and membranaceous. Corollas all tubular, oblique or 2-lipped, inflated above; the outer ones usually larger and neutral, the inner flowers bisexual; lobes 5, slender. Akenes flattened; pappus hairs short, slender, rough.

1. Cyanus L. Bachelor's Button. Stem erect, slender, grooved, 1–2 ft. high, somewhat branched. Leaves acute, sessile, narrow, entire or few-lobed. Peduncles covered with cottony wool. Heads ½–1 in. in diameter, cobwebby. Ray-like flowers few, large, bright blue or pink; those of the disk smaller. Cultivated from Europe and escaped from gardens.

2. C. americana Nutt. Prairie Star Thistle. Annual; stem stout, little or not at all branched, 2–6 ft. high. Leaves entire or minutely toothed, the basal and lower ones spatulate or oblong, petioled, the upper narrower, sessile and mucronate. Heads solitary at the summit of the stem or tips of the branches; involucre nearly hemispherical, the bracts ovate or lanceolate, with comb-like appendages. Flowers pink or purple, the marginal ones ray-like. In dry plains, especially S.W.

II. LIGULIFLORÆ

XIV. CICHORIUM L.

Perennial herbs with spreading branches; juice milky. Leaves radical and alternate, toothed or pinnately cut. Heads axillary; involucre cylindrical; bracts in 2 rows, the inner row erect, united at the base, the outer shorter; receptacle flattish. Corollas blue, pale pink, or yellow. Upper part of the style and its slender arms hairy. Akenes crowded on the

hardened receptacle, firmly covered by the stiff involucre, obovoid or top-shaped, not beaked; pappus 1 or 2 rows of short scales.

1. C. Intybus L. Chicory, Blue Dandelion, Blue Sailors. Root very long, stout, and fleshy; stem 1–3 ft. high, angled and grooved; branches straight and stiff. Basal leaves and lower stem leaves runcinate; upper stem leaves oblong or lanceolate, clasping, those of the branches reduced to bracts. Flowers very showy, usually bright blue, rarely pinkish-white. Introduced from Europe; a troublesome weed in grass lands and common in waste places, particularly in New England.

XV. KRIGIA Schreber. (ADOPOGON)

Small, annual or perennial herbs. Leaves mostly basal, toothed or lyrate. Heads several–many-flowered; scales of the involucre about 2-rowed, thin. Akenes short, truncate; pappus in 2 rows, the outer one of thin, blunt, chaffy scales, the inner one of slender bristles. Corollas yellow.

1. K. virginica Willd. Annual; scapes usually 2–5 from one root, slender. Leaves mostly lyrate, smooth and with a bloom, the earlier ones rounded or spatulate. Scales of the involucre linear-lanceolate, nearly equal, spreading. Akenes top-shaped, reddish-brown, crowned with 5 wedge-obovate scales and 5 rough white bristles.

2. K. Dandelion Nutt. Perennial, from slender tuber-bearing roots; scapes leafless, 6–18 in. high. Leaves entire or nearly so, varying from spatulate-oblong to linear-lanceolate. Akenes more slender than in No. 1; pappus consisting of 10–15 small, oblong, chaffy scales, and 15–20 bristles. In moist ground, especially S.

3. K. amplexicaulis Nutt. Stem 12–18 in. high, often 2–3 from the same root, mostly 2-forked or 3-forked at the summit. Basal leaves 3–6 in. long, lanceolate, entire, toothed or rarely pinnately cut, clasping at the base; stem leaves 1–3. Akenes and pappus about as in No. 2. Moist banks.

XVI. LEONTODON L.

Perennial, scape-bearing herbs; juice milky. Leaves all basal, toothed or pinnatifid, often runcinate. Heads on simple or branched scapes, yellow; bracts of the involucre many, in several rows, the anther smaller; receptacle flat, naked. Arms of the style linear, obtuse, hairy. Akenes cylindrical, grooved, transversely wrinkled; beak short; pappus hairs stiff, in 1 or 2 rows.

1. L. autumnalis L. Scape usually branching, 5–15 in. high, bracted; peduncles enlarged above. Rootstock truncate. Heads 1½–1 in. or more in diameter; involucre top-shaped or bell-shaped. Pappus of a single row of tawny hairs. Fields and roadsides, especially N.E. Naturalized from Europe.

XVII. TARAXACUM Haller

Stemless perennial or biennial herbs. Leaves in a flattish tuft, pinnately cut or runcinate. Head many-flowered, large, solitary, yellow, borne on a hollow scape, which is short at first but lengthens after flowering. Involucre composed of a single row of long, erect inner scales, and a set of much shorter ones outside and at the base of the former ones. Akenes cylindrical or spindle-shaped, with 4–5 rough ribs, the apex tapering into a bristle-like beak which bears a short, broadly conical tuft of soft white hairs.

1. T. officinale Weber. DANDELION. Outer involucre reflexed; inner involucre closing over the head, after the flowers are withered, and remaining shut for some days, then opening and allowing the akenes to form a globular head. Root stout, bitter, medicinal. Young leaves eaten as a pot-herb ("greens") in spring — the plant often cultivated for the leaves by market-gardeners.

XVIII. SONCHUS L.

Annual or perennial. Leaves mostly toothed or pinnately cut, prickly margined. Heads in corymbs or panicles; bracts in several series, the outer shorter; receptacle naked. Flowers yellow, rays truncate, 5-toothed at the apex. Akenes oval to oblong, compressed, ribbed, truncate at the apex; pappus of numerous soft white hairs.*

1. S. oleraceus L. SOW THISTLE. Annual; stem erect, branched, smooth, 2–6 ft. high. Leaves spiny-toothed, the lower long-petioled, very irregularly cut or pinnatifid, the upper clasping by an eared base. Involucre downy when young. Akenes channeled and transversely wrinkled. In waste places on very rich soil.*

2. S. asper Vill. SPINY SOW THISTLE. Annual; stem erect, smooth, branched but little, 2–6 ft. high. Leaves undivided, spatulate to oblanceolate, fringed with spiny teeth; the lower narrowed into a petiole, the upper clasping by an eared base, the ears rounded.

Heads numerous; involucre glabrous. Akenes flattened, margined, 3-nerved on each side, smooth. In waste places.*

XIX. LACTUCA L.

Annual, biennial, or perennial; stems leafy. Leaves entire to pinnately cut. Heads panicled; involucre cylindrical; bracts unequal, overlapping in 2 or more rows, the outer shorter; receptacle naked. Flowers blue, yellow, or white; rays truncate, 5-toothed at the apex. Akenes compressed, ribbed, the apex contracted into a slender beak, which is enlarged into a disk bearing the soft, hairy, white or tawny pappus.*

1. L. canadensis L. Wild Lettuce. Biennial; stem erect, smooth, hollow, branched above, 3–10 ft. high. Leaves lanceolate to spatulate, pale beneath, the lower petioled and pinnately cut, the upper sessile, clasping, and nearly entire. Heads numerous, about 20-flowered; flowers yellow. Akenes oval, flat, 1-ribbed on each side, minutely roughened, about as long as the beak; pappus white. In waste places.*

2. L. acuminata Gray. Blue Lettuce. Stem very leafy, smooth, paniculately branched above, 3–6 ft. high. Leaves ovate to lanceolate, taper-pointed, often hairy beneath; the lower on winged petioles and often sinuate-lobed, the upper sessile. Heads racemed, on divergent and bracted peduncles; flowers blue. Akenes slightly compressed, beak very short; pappus white. In waste places.*

XX. AGOSERIS Raf.

Herbs, usually appearing stemless. Basal leaves tufted, usually sessile. Head solitary, large, yellow or rarely purple, on a naked or bracted scape; bracts of the involucre overlapping in 2 or 3 rows; receptacle flat, naked or pitted. Akenes smooth, 10-ribbed, with or without a beak; pappus of abundant slender white bristles.

B. Fl. species 1 (*Nothocalais*).

1. A. cuspidata Steud. Scape 1 ft. or more high. Leaves lanceolate, taper-pointed, woolly-margined. Involucral scales lanceolate, sharp-pointed. Akenes beakless. Prairies and plains W.

2. A. glauca Steud. Scape stout, 1–2 ft. high. Leaves varying from linear to oblong, entire, dentate or pinnately cut. Heads 1–2 in. in diameter. Akenes beaked. Plains W.

XXI. PYRRHOPAPPUS DC. (SITILIAS)

Annual or biennial; stem erect, leafy below, nearly naked above, smooth. Leaves oblong, toothed or pinnatifid. Heads large, long-peduncled; involucre cylindrical or spreading, the inner row of bracts erect, united at the base, the outer rows shorter and spreading; receptacle naked. Flowers yellow; rays truncate, 5-toothed at the apex. Akenes oblong, 5-ribbed, narrowed above into a long and slender beak; pappus soft, tawny, with a short, soft-hairy ring at the base.*

1. P. carolinianus DC. False Dandelion. Annual or biennial; stem glabrous, furrowed, branched above, 2–3 ft. high. Lower leaves lanceolate to oblong, entire, toothed or pinnatifid, narrowed into a margined petiole; the upper sessile, bract-like, entire. Heads few, long-peduncled; peduncles and involucre sometimes finely downy; inner bracts calloused at the apex, the outer awl-shaped and spreading. Akenes much shorter than the thread-like beak. Common in fields.*

XXII. HIERACIUM L.

Perennial herbs, often covered with glandular or star-shaped hairs; juice milky. Leaves alternate. Heads solitary, or in corymbs or panicles; bracts of the involucre many, overlapping, unequal; receptacle flattish, naked, pitted. Corollas yellow, rarely orange. Arms of the style slender and upper part of the style hairy; akenes angled or grooved, not beaked. Pappus hairs in a single row, simple, stiff, tawny or brownish, brittle. [Most of our commoner species bloom in the late summer or autumn.]

1. H. aurantiacum L. Orange Hieracium, Devil's Paint Brush. Stem leafless or occasionally with 1 or 2 small sessile leaves, clothed with long hairs. Basal leaves oblanceolate, hairy, $2\frac{1}{2}$–6 in. long. Scapes 8–24 in. high. Heads corymbed, about $\frac{3}{4}$ in. in diameter, orange-red. A common weed, naturalized from Europe.

2. H. venosum L. Rattlesnake Weed. Stem scape-like, usually leafless or nearly so, smooth, 1–2 ft. high. Basal leaves 2–5 in. long, obovate or ovate-oblong, generally purple-veined. Heads rather large, yellow, in a loose panicled corymb. Dry hills and roadsides, and in pine woods E.

GLOSSARY

OF TECHNICAL TERMS USED MAINLY IN THE FLORA

Abortive, imperfectly developed.

Actinomorphic, having radial symmetry.

Adventive, partially naturalized.

Appressed, lying flat throughout its length, used of such parts as bracts.

Awl-shaped, narrow and tapering to a point.

Awned, having a bristle-like appendage.

Awnless, not awned.

Bisexual, having both stamens and pistils in the same flower.

Caducous, falling away very early.

Capitate: (1) having a round head like the stigma of a primrose; (2) growing in heads.

Carpellary, relating to a carpel.

Chaff, small membranous scales, such as are found on disks of *Compositæ*.

Ciliate, having the margins fringed with hairs or bristles.

Clasping, partly surrounding the stem; said of the bases of leaves.

Claw, the narrowed base of a petal.

Cleft, cut halfway down.

Coated (bulbs), those with scales which completely cover them, as in the onion.

Cone, the fruit of pines, etc., with ovule-bearing scales.

Connate, united; said of opposite leaves which appear as if grown together at their bases.

Convolute, rolled up lengthwise.

Convolute

Cordate, heart-shaped.

Corm, a bulb-like, fleshy stem or base of a stem.

Crown, an inner appendage to a petal or to the throat of the corolla.

Deciduous, falling as petals do after blossoming, or as leaves of most trees except evergreens do.

Declined, directed obliquely.

Decumbent, reclining, but with the summit somewhat erect.

Dehiscent, splitting into definite parts.

Diffuse, spreading widely or loosely.

Dimorphous, occurring under two forms, as in flowers with long and with short styles.

Disk: (1) an outgrowth of the receptacle within the calyx or within the corolla and stamens; (2) the central part of the head (all but the rays) in *Compositæ*.

Dissected, deeply divided or cut into many segments.

Drupe, a stone fruit such as a peach or a plum.

Equitant, leaves astride of those within them, thus appearing in a cross section like the diagram, <<<.

Even-pinnate, abruptly pinnate, i.e. with no leaflet at the end.

Fascicle, a close cluster or bundle of flowers, leaves, stems, or roots.

Fertile, capable of producing fruit; fertile flowers, those which have pistils.

Filiform, thread-shaped.

Fleshy, succulent, thick and full of sap.

Funiculus, the little stalk which connects a seed or ovule with the placenta.

Gland: (1) a structure which secretes something, as the knobs on the hairs of sundew; (2) any knob or swelling.

Glume, one of the two sterile, chaffy bracts at the base of a grass spikelet.

Herbaceous, with no stem aboveground which lives through the winter, not woody or shrubby.

Imbricate, overlapping, as the segments of some perianths in the bud. At least one segment must be wholly outside and one wholly inside.

Imbricate

Indefinite, too many to be easily counted.

Indehiscent, not splitting open regularly.

Introduced, term applied to plants purposely brought into a region by man.

Involucrate, provided with an involucre.

Keel, the two anterior and united petals of a papilionaceous corolla.

Key, a winged fruit like that of the ash or maple.

Limb, the border or spreading part of a gamopetalous calyx or corolla.

Lobed, having divisions, especially rounded ones.

Lodicule, one of the very minute scales immediately beneath each flower in a grass spikelet.

Naturalized, term applied to plants not natives of a region but thoroughly established there in a wild condition.

Nerved, having simple or unbranched veins or slender ribs.

Ob- (in composition), signifies inversely; as, obcordate, inversely heart-shaped.

Odd-pinnate, pinnate with a single leaflet at the end of the midrib.

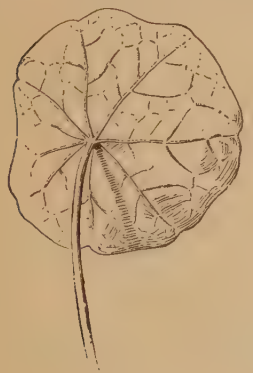
Palate, a projection in the throat of a corolla.

Palet, one of the bracts which subtend the flowers in a grass spikelet.

Papilionaceous, butterfly-shaped, like the corolla of the sweet pea.

Papillose, covered with papillæ or minute projections, like the human tongue.

Pappus, tufts of hair or other objects, representing the limb of the calyx in *Compositæ* (Fig. 30).



Peltate

Peltate, shield-shaped, that is with the stalk attached somewhere within the circumference of the leaf or other organ.

Perfoliate, with the stem apparently growing up through a leaf, as in some honeysuckles.

Persistent, not deciduous.

Pinnatifid, pinnately cleft.

Pistillate, having pistils but not stamens.

Plumose, feathered, as the pappus of thistles (Fig. 31).

Pubescent, clothed with soft hair, downy.

Punctate, marked with dots, depressions, or translucent glands.

Reflexed, bent or turned abruptly downward or backward.

Root parasite, a plant parasitic on the roots of another.

Sagittate, arrow-shaped.

Scape, a leafless flower stalk arising from the ground, as in the dandelion and cyclamen.

Scarious, thin, dry, and membranous, not green.

Sessile, without a stalk.

Simple (stem), unbranched.

Spadix, a spike with a fleshy axis, like that of the Indian turnip or the "calla."

Spathe, a large bract which incloses a flower cluster, often a spadix.

Staminate, having stamens only.

Standard, the posterior petal of a papilionaceous corolla.

Sterile: (1) barren, as a flower without a pistil or an antherless stamen; (2) staminate or male, said of flowers.

Striate, marked with fine longitudinal parallel lines.

Sub- (in composition), somewhat, as subglobose.

Subtend, to extend beneath as a bract in the axil of which a flower is borne.

Succulent, fleshy or juicy.

Three-ranked, with three vertical rows on a stem or axis.

Throat, the top of the tubular part of a sympetalous corolla.

Truncate, appearing as if cut squarely off, as the leaves of the tulip tree.

Tubercled, covered with warty growths.

Two-lipped

Tubercular, having tubercles, or like a tubercle.

Utricle

Two-lipped, having the limb of the calyx or corolla divided into two lip-like portions, as in the *Labiatæ*.

Two-ranked, with two vertical rows on a stem or axis.

Unisexual, having in each flower only stamens or only pistils, not both.

Utricle, a small bladdery ovary wall.

Versatile, turning freely on its support, as an anther on its filament.

Whorled, arranged in a circle around an axis, as the leaves of some lilies.

Wings, the side petals of a papilionaceous flower.

Zygomorphic

Zygomorphic, having bilateral symmetry, as the corollas of many *Leguminosæ*.

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All names in italics are synonyms, — the preferred names are in Roman type

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Y0-CJI-817